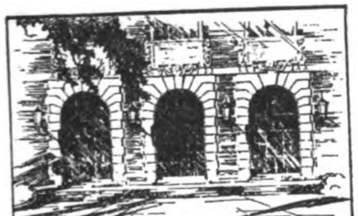

44TH CONGRESS, 1st Session. } HOUSE OF REPRESENTATIVES. { Ex. Doc. No. 81.

REPORT OF THE SUPERINTENDENT

OF THE

UNITED STATES COAST SURVEY,

SHOWING

THE PROGRESS OF THE SURVEY

DURING

THE YEAR 1875.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1878.

LETTER

FROM

THE SECRETARY OF THE TREASURY,

TRANSMITTING

REPORT OF THE SUPERINTENDENT U. S. COAST SURVEY FOR THE YEAR 1875.

JANUARY 18, 1876.—Referred to the Committee on Commerce and ordered to be printed.

TREASURY DEPARTMENT, *December* 29, 1875.

SIR: I have the honor to transmit, for the information of the House of Representatives, a report made to this department by C. P. Patterson, esq., Superintendent of the United States Coast Survey, showing the progress in that work during the year ending June 30, 1875; and also an engraved map, illustrating the general progress in the survey of the Atlantic, Gulf, and Pacific coasts of the United States.

I have the honor to be, very respectfully,

B. H. BRISTOW,
Secretary of the Treasury.

Hon. MICHAEL C. KERR,
Speaker of the House of Representatives, Washington, D. C.

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REPORT.

COAST SURVEY OFFICE,
Washington, D. C., October 15, 1875.

SIR: In accordance with law, I have the honor to present my report showing the progress, during the year from July 1, 1874, to July 1, 1875, in the survey of the Atlantic, Gulf, and Pacific coasts of the United States.

Field-work has been well advanced in triangulation and topography, as will be seen by the synopsis in Appendix No. 1, which states the number of surveying parties and their distribution along the coast.

The inshore hydrography, favored by provision made in the last and the preceding Congress for the construction of several vessels, has been pushed as actively as the means allowed. More are, however, needed, as was explained in my report of last year, the land-work being yet in advance of the inshore hydrography, and much remains to be done in the marine development off shore.

On the Pacific coast, we have only one sea-going steamer; but the energetic naval officer in command has already decreased the arrearage in coast-soundings which was outstanding at the opening of the year 1874. It is gratifying to record also that hydrographic progress on the Atlantic coast has profited by able discrimination at the Navy Department in the assignment of several accomplished officers. As yet, the provision for them in vessels adapted to the work is inadequate, but it will be kept in view as a duty to urge the construction of a few vessels in addition, to insure the completion of hydrography in all cases in the season in which provision is made for it by land-operations. Apart from this aim, and as explained in previous reports, most of the smaller vessels used for prosecuting the coast-triangulation and topography are worn out. Nine, used for several years merely as quarters, have been disposed of within the present year. The one last offered for sale, under the sanction of the Treasury Department, was twenty-nine years old. Of the class of vessels here referred to, and all of which have become useless by long service, none were built under the control of the Hydrographic Division of the Survey. Most of them, unseaworthy for years, have served as uncomfortable quarters for parties working near the ports at which the hulks were laid up.

The first direct provision by Congress for means of transit at sea adapted to the requirements of the service took effect at the end of the year 1871, when two steam-vessels were built in accordance with plans furnished by the hydrographic inspector. Both of these vessels have justified my expectation in their construction. Subsequent appropriation provided for the construction of several steamers and schooners, each of which, in plan and arrangement, has been the subject of careful study in the office, based on foresight of the work in which the vessel was to be employed, whether in deep-sea soundings, ordinary inshore hydrography, or in the development of comparatively shallow bays and sounds along the southern coast. For efficiency in prosecuting the hydrography of the Pacific coast, one steamer and two schooners are needed, and two others are requisite to replace schooners that have been worn out in service on the Atlantic and Gulf coast.

On the 1st of October, detailed estimates were submitted for continuing the field-work and hydrography of the coasts of the United States during the fiscal year 1876–'77. As heretofore, a copy will be included in this report, preceded by a brief recapitulation, to show the assignment of parties in the operations of the year ending June 30, 1875. In the body of the report, more extended mention will be made of the several items of work prosecuted in the course of the year under the following heads: Soundings in the Gulf of Maine; also, on Jeffrey's Bank, Cashe's Ledge, and Jef-

frey's Ledge; development of Platt's Bank, and of dangers to navigation near the Isles of Shoals; survey of the northwestern part of Mount Desert Island and soundings in the adjacent waters; topography of the shores and hydrography of Eggemoggin Reach; survey of numerous islands near Isle au Haut and in the eastern part of Penobscot Bay, and of the bay-shore between Castine and Bucksport, Me.; soundings in Penobscot River near Winterport; tidal observations at North Haven, on the Fox Islands, Penobscot Entrance; determination of height and of co-efficient of refraction near Camden, Me., and of geographical points by triangulation in New Hampshire; tidal observations at Boston navy-yard; hydrography westward of Monomoy Peninsula, including the vicinity of Chatham Roads; triangulation and topographical survey of Taunton River, Mass., from Fall River to Somerset; special observations on currents and soundings in Providence Harbor and Seekonk River for the use of harbor commissioners; survey of the shores of Thames River, Conn., and soundings between the United States naval station and Norwich; topography of New Haven Harbor; determinations in position of light-houses at the east entrance of Long Island Sound; hydrography in that vicinity, and special examination for sailing-courses into the harbors between Point Judith and New York; survey of Port Jefferson and soundings in the adjacent waters; triangulation near the boundary-line between Massachusetts and New York; latitude and azimuth determined at Cheever Station, near Port Henry, at Mount Merino, near Hudson, N. Y., and at Rouse's Point; shore-line survey and hydrography of Lake Champlain extended from Four Brothers southward to Whitehall, including detailed surveys of the vicinity of Crown Point and Ticonderoga; topography of the shores of Hackensack River, N J.; angular measurements at Beacon Hill and Weasel Mountain; preliminaries for determining points in New Jersey; observations for deducing transverse curves of velocity in the waters of Hudson River, East River, and the main channel of New York Harbor; tidal observations at that port; soundings in West Bank Channel and near South West Spit in New York Bay; topography and hydrography of Great South Bay, Long Island, between Islip and Howell's Point; survey of the west side, and soundings through Barnegat Bay, N. J.; hydrography of the entrance and approaches to Little Egg Harbor; preliminaries for determining points in the eastern part of Pennsylvania; triangulation and soundings for light-house purposes in Delaware River at Liston's Tree and near the mouth of the Schuylkill River; magnetic declination, dip, and intensity determined at the standard station in Washington City, D. C.; special topographical survey of Craney Island, Va., and soundings in the channel between it and the main shore; tidal observations at Fortress Monroe; survey and hydrography of James River from Sloop Point upward to the vicinity of City Point, and of the Chickahominy from Ship Yard upward to Forge Bridge; primary triangulation extended southward along the Blue Ridge to Fork Mountain; reconnaissance from that station westward to the Kanawha; triangulation of Pamplico Sound, N. C., completed and connected with the primary base-line on Bodie's Island; survey of the shores extended from Juniper Bay northward and eastward to the Roanoke Marshes; hydrography of the sound extended from Shoal Point southward, including Yesocking Bay; detailed survey of the coast of South Carolina, and soundings through the water-passages between Cape Romain and Sullivan's Island; preliminaries for tracing the altered shore-line at Hunting Island, S. C.; hydrography of Savannah River from the bar upward to the head of Elba Island; hydrography of the coast of Florida north and south of Saint Augustine; survey and sounding of the inland sea-water channels south of Mosquito Inlet, including the head of Indian River; detailed survey of the Tortugas Islands and hydrography of the harbor and reef; triangulation and topography of Tampa Bay and hydrography of the bar and approaches; tidal observations continued at Saint Thomas, West Indies; topography and hydrography of the western coast of Florida between Pepper Keys and Ocilla River; hydrography of the vicinity of Cape San Blas and of Saint Joseph's Bay; triangulation and reconnaissance westward and northward of the base-line near Atlanta, Ga.; latitude, azimuth, and magnetic elements determined at primary stations in that vicinity; preliminaries for determining points in the State of Kentucky; special shore-line survey and hydrography of the mouths of the Mississippi; observations on density and relative to the volume of water-discharge; the bar and approaches to the delta sounded, and deep-sea lines of soundings run in the Gulf of Mexico; topography of the Mississippi above New Orleans; triangulation in Missouri extended westward from Saint Louis to the vicinity

of Gasconade River; reconnaissance for intervisible stations near the Ohio River; measurement of base-line at Spring Green, Wis., preliminary to the determination of points in Wisconsin; and hydrography completed in San Antonio, Musquit, and Aransas Bays, Texas. On the Pacific coast, a detailed survey of the adjacent coast of California and development of the approaches and channels of Newport Bay, near Point Lasuen; topography of Santa Cruz Island, and hydrography of its vicinity; triangulation across the Santa Barbara Channel from Gaviota Pass; hydrography of San Luis Obispo Bay and development of dangers to navigation near Point San Luis; special topographical survey of Point Sur for the Light House Board; tides and currents observed in San Francisco Bay; soundings between Yerba Buena and Oakland and abreast of Saucelito; development of a shoal off the South Farallon; buoyage of Noonday Rock; inshore soundings completed between Cape Mendocino and Rocky Point; reconnaissance for intervisible stations from the Pacific coast across the Sierra Nevada Mountains to the vicinity of Austin, Nev.; triangulation and topography north and south of Ten Mile River, Cal., completing the detailed survey between Point Cabrillo and Shelter Cove; discovery and determination in position of a dangerous rock in the passage used by coasters between Blunt's Reef and Cape Mendocino; triangulation of the coast between Rocky Point and Klamath River, including the vicinity of Redding's Rock; inshore soundings extended along the coast of California from False Klamath northward to Mack's Arch, on the coast of Oregon; reconnaissance of the summit and region of Mount Shasta as a center for triangulation; topography of the shores of Columbia River, Oreg., extended from Oak Point to Smith's Island; tidal observations at Astoria; triangulation and topography of the coast from Point Adams south toward Nehalem River; detailed survey of the eastern shores of Duwamish Bay, W. T., including the town of Seattle and part of Lake Union; tidal observations at Port Townshend, W. T.; surveys of harbors on the coast of Alaska, with determinations of latitude, azimuth, the magnetic elements, and observations for correcting errors in geographical positions as now appear on charts, and for the height of Mount Crillon, Mount Fairweather, Mount Saint Elias, and other prominent landmarks on the coast of Alaska.

Progress in office-work has been kept up to that of the field-work of the preceding season. Computations of the current geodetic, trigonometrical, and tidal observations have been duly made, including the preparation of records and results for publication; tide-tables for the principal ports of the United States for the year 1876 have been published; the drawing of fifty-four charts has been in progress, and of this number sixteen have been completed; twenty-nine sketches of harbors on the coast of Alaska have been drawn for publication by lithography; eleven new copper-plate charts have been begun, thirty-eight have received additions by engraving, and eleven have been completed. An aggregate of 14,000 copies of charts has been issued in the course of the year. The first volume of the Coast Pilot for the Atlantic Coast, giving sailing directions for harbors between Eastport and Boston, has been published, and a second edition, illustrated by charts, is in preparation. The second volume, comprising the coast from Boston to New York, is well advanced toward publication.

ESTIMATES.

The estimates for continuing the survey of the Atlantic and Gulf coasts of the United States are intended to provide for the following progress:

FIELD-WORK.—To continue the topography of the western shore and islands of Passamaquoddy Bay and its estuaries; of the coast and eastward of Penobscot Bay toward Narraguagus Bay; to finish work on the islands and shores of Penobscot Bay and River; to continue the determination of heights at some of the principal trigonometrical points between Boston and the Saint Croix, and of co-efficients of refraction; to complete the hydrography of Penobscot Bay and River, and continue soundings in the coast-approaches eastward of Penobscot Bay; to continue a topographical and hydrographic survey of Portsmouth Harbor; to make such additional triangulation as may be requisite for that and other surveys on the eastern coast, and determine the position of new light-houses between Eastport, Me., and New York; to continue soundings along the coast of Maine, and other offshore hydrography between Cape Cod and Manan, and make special examination for the sailing lines for charts; to continue tidal observations, and to make

such astronomical and magnetic observations as may be required; to continue such topographical and hydrographic resurveys of the coast between Cape Cod and New York as may be found necessary; to continue the survey of the Connecticut River from its mouth to Hartford; to make such examination as may be required in New York Harbor, and such surveys in its vicinity as may be found necessary; to make, at this port, observations on tides and currents; to extend the plane-table survey of the Hudson River above Haverstraw; to continue the triangulation between the Hudson River and Lake Champlain; to make the requisite astronomical observations; to continue the topographical and hydrographic surveys of the coast of New Jersey, and the resurveys of the hydrography of Delaware Bay and River; to connect the Atlantic triangulation with that of Chesapeake Bay, near the boundary-line between Maryland and Virginia; to complete the detailed survey of James River, Va., including the hydrography, and continue the plane-table survey of the Potomac River; to continue southward the main triangulation along the Blue Ridge, parallel with the coast, including astronomical and magnetic observations; to continue the supplementary hydrography between Cape Henlopen, Del., and Cape Henry, Va., and in Chesapeake Bay, and also the tidal observations; to measure a base-line of verification and determine azimuth for the coast-triangulation south of Cape Lookout; to make the astronomical and magnetic observations requisite; to continue the offshore hydrography between Cape Henry and Cape Fear; to complete the hydrography of Pamplico Sound and its rivers, and that of Core and Bogue Sounds and sound the entrance to Cape Fear River; to extend northward the primary triangulation along the eastern and southern slopes of the Alleghanies in North Carolina and Alabama; to continue the topographical and hydrographic survey of rivers near the coast of South Carolina and Georgia; to determine azimuth for the triangulation of the coast of South Carolina and Georgia; to continue the detailed survey of the sea-islands and water-passages between Charleston and Savannah, and to make tidal observations; to make a hydrographic resurvey of Georgetown Harbor, S. C., and its approaches, and continue the offshore hydrography between Cape Fear, N. C., and the Saint John's River, Fla.; to continue southward from Canaveral the triangulation, topography, and hydrography of the eastern coast of Florida, including Indian River; to continue the triangulation, topography, and hydrography of Saint John's River; to make the requisite astronomical observations, to continue hydrography off the eastern coast of Florida from Mosquito Inlet to the southward; to continue soundings and observations for sea-temperatures in such parts of the Gulf Stream as may be deemed advisable, between the west end of Cuba and Nova Scotia, and dredging along the coast within the same limits, in conjunction with the United States Commission on Fish and Fisheries; to continue the astronomical and magnetic observations requisite between Cape Florida and Pensacola; to continue the triangulation, topography, and hydrography of the western coast of Florida south of Tampa Bay, and to the southward of Charlotte Harbor, of the coast of the peninsula between Tampa Bay and Cedar Keys, and between Appalachee Bay and Pensacola; to run lines of soundings and make observations of sea-temperatures in the Gulf of Mexico, and develop the hydrography of the Gulf coast included in the field-operations; to connect the trigonometrical survey of the Mississippi River at New Orleans with that of Lake Borgne and Lake Pontchartrain, and continue the trigonometrical, topographical, and hydrographic survey of Lakes Pontchartrain and Maurepas, and of the Mississippi River above Carrollton, La.; to determine geographical positions, and make the astronomical and magnetic observations required; to extend the triangulation, topography, and hydrography of Louisiana westward of the Mississippi delta, and continue the hydrography of the Gulf of Mexico between the mouth of the Mississippi and Galveston, Tex.; to continue the triangulation, topography, and hydrography of the coast of Texas westward, between Sabine Pass and Galveston, and between Corpus Christi and the Rio Grande; to measure a base-line of verification, and make the astronomical and magnetic observations requisite between Sabine Pass and the Rio Grande; to continue the hydrography of the approaches to the coast of Texas; to continue the determination of the positions of new light-houses and life-saving stations along the coast between New York and the Rio Grande; to continue the field-work for the description and verification of the work for the Coast Pilot; and to continue the organized system of magnetic observations required for a complete magnetic survey.

OFFICE-WORK.—To compute results from the field-operations made along the Atlantic and Gulf coasts, including astronomical, geodetic, geographical, magnetic, and tidal work; to continue the reproduction of the original topographical maps, and to plot the hydrographic charts; to continue the drawing of the general chart of the coast from Quoddy Head to Cape Cod, and of Charts Nos. 1 and 2, showing the coast of Maine between Saint Croix River and Petit Manan light-house; to continue drawing and engraving for Chart No. 3, which includes Frenchman's Bay, Mount Desert Island, Blue Hill Bay, Isle au Haut Bay, and their approaches, also of local charts of Mount Desert Island, Eggemoggin Reach, and Penobscot Bay east, and to draw and engrave the chart of Lake Champlain; to continue the drawing and engraving of charts of Thames River and of Connecticut River to the head of navigation; to complete the engraving of Chart No. 7 from Seguin Island to Kennebunkport, and to draw and engrave the resurvey of the entrance to Nantucket Sound including Monomoy Shoals; to draw and engrave the resurvey of the eastern entrance to Long Island Sound, and to continue work on a new chart of that sound; to complete the engraving of Chart No. 21, showing the coast between Sandy Hook and Barnegat Inlet; to continue the drawing and engraving of Nos. 22 and 23, between Barnegat and Cape May; to make additions to the charts and sketches between New York and Cape Henry; to continue the drawing and engraving of a new chart of Delaware Bay and River, and to complete that of James River; to continue the drawing and engraving of the general chart of the coast between Cape Henry and Cape Lookout, and of Charts Nos. 37, 39, 42, 43, 44, 45, 46, and 47, showing parts of the Atlantic coast between Cape Henry and Cape Lookout, including Pamplico Sound; to continue engraving on the general chart of the coast between Cape Hatteras and Cape Romain, and the drawing and engraving of that of the coast between Cape Romain and the Saint Mary's River, and of Charts Nos. 51 and 52, between Cape Fear and Winyah Bay; to continue the drawing and engraving of a new chart of Georgetown Harbor, S. C., and to make additions to the charts between Cape Henry and the Saint Mary's River; to continue the drawing and engraving of the general chart of the coast from Saint Mary's River to Cape Canaveral, and of Charts Nos. 59 and 60, from Saint Augustine to Cape Canaveral, and make additions to the charts of the coasts between Saint Mary's River and Cape Florida; to continue the drawing and engraving of Charts Nos. 80, 81, 82, 83, 84, 85, 86, and 87, showing the Gulf coast between Chassahowitska River and Pensacola Entrance, and of the charts of Tampa Bay; to engrave the chart of Saint Joseph's Bay and the chart of Saint Andrew's Bay; to complete the drawing and engraving of Charts Nos. 91, 92, 93, 94, and 95, showing Lake Borgne, part of Lake Pontchartrain, Isle au Breton Sound, and the Mississippi River between New Orleans and the Gulf of Mexico, and the general chart showing the sea-approaches to the Mississippi River; to continue the drawing and engraving of the general chart of the coast of Louisiana and Texas from Atchafalaya Bay to Galveston; to continue the drawing and engraving of that between Galveston and the Rio Grande, and of Charts Nos. 109 and 110, Aransas Bay, Copano Bay, and Corpus Christi Bay; for material for drawing, engraving, map-printing, for electrotyping, photographing, for instruments and apparatus.

Total for the Atlantic and Gulf coasts, involving work on the coast of the following States, viz, Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas, will require $380,000.

The estimates for continuing the survey of the Pacific coast of the United States are intended to provide for the following progress:

FIELD-WORK.—To make the requisite observations for latitude, longitude, azimuth, and the magnetic elements at stations along the Pacific coast of the United States; to continue offshore soundings along the coast of California, Oregon, and Washington Territory, and tidal observations at San Francisco, Astoria, Port Townshend, and such other localities as may be necessary; to continue the main coast-triangulation from Monterey Bay to the southward, or from Point Conception to the northward, and from San Pedro toward San Diego, including the islands off that part of the coast; to continue reconnaissance for the main triangulation upon the mainland from Point Conception to San Diego, from Russian River to the northward, from Columbia River north to Puget Sound, or south up the Willamette Valley; to continue the reconnaissance for and commence the

rimary triangulation through the Sacramento and San Joaquin Valleys; to continue the coast-triangulation and topography from Newport, Los Angeles County, toward San Diego, and that of the islands off that coast; to continue the tertiary triangulation and topography of the coast north of Point Conception toward Point Sal, or the tertiary triangulation and topography from Point Buchon toward San Simeon; to continue the hydrography between San Diego and Point Conception, between Point Conception and Monterey Bay, develop the hydrographic changes in San Francisco Bay and its approaches, extend hydrography between Cape Mendocino and the Klamath River, between Cape Sebastian and Port Orford, north and south of, and in the approaches to, the Columbia River; to continue the hydrography of Puget Sound and adjacent waters; to observe currents along the coast and take soundings and temperature-observations in the California branch of the Kuro-Siwo Current, and execute such other hydrographic work as local demands may require; to continue tidal and current observations at the Golden Gate, and observations on the ocean-currents along the coast of California; to continue the triangulation and topography of the coast between Bodega Bay and Point Arena, between Cape Sebastian and Port Orford; to continue the triangulation, topography, and hydrography of the Columbia River; to complete the detailed survey between Cape Sebastian and Crescent City, and offshore hydrography at Crescent City Reef; to measure a base-line and continue the triangulation of the Strait of Fuca, and the triangulation and topography of Puget Sound and adjacent waters; to continue the reconnaissance of the coasts and islands of Alaska, with observations for tides and currents, and to make the requisite astronomical and magnetic observations; to continue the field-work for the description of the coast and verification of the Coast Pilot of the coasts of California, Oregon, and Washington Territory, and to continue the organized system of magnetic observations required for a complete magnetic survey.

OFFICE-WORK.—To make the computations from the observations recorded in the field, including astronomical, geodetic, geographical, magnetic, and tidal observations; to continue the reproduction of the original topographical maps, and to plot the hydrographic charts; to draw and engrave the additions on the general chart of the Pacific coast of the United States; to continue the drawing and engraving of the charts of the coast from San Diego to Point Conception, Nos. 1, 2, and 3; to complete the engraving of a new chart of San Francisco Entrance and Harbor from resurveys; to continue the drawing and engraving of charts of the coast from Point Arena to Cape Mendocino, No. 7, of that from Cape Mendocino to Saint George's Reef, No. 8, and of that from Saint George's Reef to the Umpquah River, No. 9, Shoalwater Bay, Puget and Washington Sounds; to continue the drawing and engraving of the chart of Columbia River and of the local harbor-charts of the coast, with those of the northwestern coast.

Total for the Pacific coast, involving work on the coast of the States of California and Oregon and Washington Territory and Alaska, will require $245,000.

For extending the triangulation of the Coast Survey to form a connection between the system of triangulation along the Atlantic and Gulf and Pacific coasts of the United States, and assisting in the State surveys, involving work in New Hampshire, Vermont, Connecticut, New York, Pennsylvania, New Jersey, Virginia, West Virginia, North Carolina, Alabama, Missouri, Illinois, Wisconsin, Kentucky, Kansas, California, Nevada, and Utah Territory, will require $90,000.

For repairs and maintenance of the complement of vessels used in the Coast Survey will require $50,000.

For continuing the publication of the observations made in the progress of the Coast Survey will require $8,000.

For general expenses of all the work, rent, fuel; for transportation of instruments, maps, and charts; miscellaneous office expenses, and for the purchase of new instruments, books, maps, and charts, will require $34,600.

The annexed table shows, in parallel columns, the estimates for the fiscal year 1875–'76, and the estimates herein submitted for the fiscal year 1876–'77.

Objects.	Estimated for 1875–'76.	Estimated for 1876–'77.
For continuing the survey of the Atlantic and Gulf coasts of the United States, including compensation of civilians engaged in the work, and pay and rations of engineers for steamers used in the Coast Survey, per acts of March 3, 1843, and June 12, 1858	$400, 000 00	$380, 000 00
For continuing the survey of the western coast of the United States, including compensation of civilians, and pay and rations of engineers for the steamers used in the work, per act of September 30, 1850	260, 000 00	245, 000 00
For extending the triangulation to join the survey of the Atlantic and Pacific coasts of the United States, and assisting in the State survey, including compensation of civilians engaged in the work, per act of March 3, 1871	70, 000 00	90, 000 00
For repairs and maintenance of the complement of vessels used in the Coast Survey, per act of August 18, 1856	50, 000 00	50, 000 00
For continuing the publication of observations made in the progress of the Coast Survey, including the compensation of civilians engaged in the work, the publication to be made at the Government Printing Office, per act of March 3, 1869	8, 000 00	8, 000 00
For general expenses of all the work, viz: Rent, fuel, transportation of instruments, maps and charts, for miscellaneous office expenses, and for the purchase of new instruments, books, maps, and charts	37, 000 00	34, 600 00
Total	825, 000 00	807, 600 00

DISCOVERIES AND DEVELOPMENTS.

Particulars in regard to most of the items which belong under this head were published as *Notices to Mariners* in the course of the present year. As special results, they are reported from the chiefs of parties without delay, and the notice in each case issues immediately after the receipt at the office of sufficient information in regard to the danger. Under the heads of Section I, Section V, Section VI, and Section X, in this report, further mention will be made of the items here recapitulated:

1. A bank found off the coast of Maine (Platt Bank), 10 miles long and 5 miles wide, and having at places on it only 29 fathoms of water.
2. Shore-line changed by sea encroachment at the north end of Hunting Island, coast of South Carolina.
3. Increased depth of the channel into Saint Augustine Harbor, Fla.
4. Water in 21 fathoms at a spot off Matanzas Inlet, Florida, frequently agitated, and when turbid appearing as a shoal.
5. Southwest entrance to Tampa Bay, Florida, sounded, showing 19 feet on the bar at mean low water and a straight channel. The north channel into that bay has 21 feet.
6. A large rock found two miles southwest of Gadsden's Point in Tampa Bay, Florida, with peaks, having only 4 feet of water at low tide.
7. Submarine cañon off the Pacific coast, southward of Santa Cruz Island, Cal.
8. Three sunken rocks, dangerous to navigation, near Point San Luis, Cal.
9. A rock off the South Farallon.
10. A very dangerous rock inside of Blunt's Reef off Cape Mendocino, Cal.
11. A sunken rock off the Pacific coast and opposite to the boundary between California and Oregon.
12. A harbor of refuge developed near Mack's Arch on the coast of Oregon.

Appliances in marine engineering have recently given promise of the removal, by blasting, of the upper parts of isolated rocks that are now dangerous to navigation. Amongst these is "*Noonday Rock*" in the Pacific, and more than 30 miles southwest of San Francisco Entrance. In regard to its removal, arrangements have been made by Lieut. Col. C. Seaforth Stewart, United States Corps of Engineers, under whose direction Lieutenant Weeden employed a diver to search near the buoy set by the hydrographic party, and found two additional sharp points of rock, one of them having on it only, 14 feet of water at low tide. Specifications embodying full information have been issued since by Lieutenant-Colonel Stewart, and it is hoped that the pinnacles of "*Noonday Rock*" that were dangerous to large vessels may be blasted away before the close of the present year.

The ship Noonday, on the 2d of January, 1863, struck on one of the sharp points, and in less than two hours sank in 40 fathoms.

Continuous watching off shore by one of the land-parties, while working near Cape Mendocino, without seeing any break, even in stormy weather, in water in which the same party subsequently found sharp rocks, renders it extremely probable that on some of the most dangerous points of rock the sea may never break at any time.

TIDES OF NEW YORK HARBOR.

The continuous tidal observations recorded at the station in New York Harbor, between the years 1856 and 1874 inclusive, embracing a complete series of nineteen years, have been recently discussed by Prof. William Ferrel, of the Coast Survey.

The amplitudes and epochs of all of the principal inequalities in the heights and lunitidal intervals, found needful for either theoretical purposes or for practical application in forming tables for the predictions of the tides, have been determined.

The result of the discussion shows that the same general type of tides prevails here which is found at Boston and along the New England coast. This consists in a very small solar tide and declinational inequality, and a proportionally large lunar parallactic inequality, and likewise a very small diurnal tide.

The most interesting result reached by Professor Ferrel, and having a bearing upon the theory of the tides; one, moreover, which seems peculiar to the station, is that the lunar diurnal tide at New York does not vanish when the moon is on or near the equator, but is a minimum, and still about one-third as large as the maximum at the times of greatest declination.

Practical tables have been formed from the results of the discussion, to be used in computing the heights and times of high water in New York Harbor, and these are now being applied in computing them for the year 1877. The results of the discussion, and also the practical tables for computing the tides, are given in Appendix No. 12.

TRANSIT OF VENUS.

At the date of my last annual report, two parties of Coast Survey assistants, organized under the auspices of the commission which was authorized by Congress to arrange for observing the transit of Venus in December, 1874, had left our shores, one of the parties destined for Japan, the other for Chatham Island in the South Pacific Ocean.

In forethought and preparations by the commission, nothing was omitted that could add to efficiency in the arrangements desirable for success in the observations. With reference alone to the parties of Coast Survey observers, the stations selected and approved by the commission were such that, with clear weather on the day of transit, a fair value of the solar parallax might be deduced from observations recorded at these positions. To this end, provision was made for observing by two methods:—Halley's, depending upon the observed duration of the transit; and the photographic method, which is relied on to give a record of the apparent path of Venus across the sun's disc. The instrumental equipment included also means for determining the latitude and longitude of each of the stations, so that, in the event of partial success in observing the transit, the computer might introduce a conditional equation for any single observation of ingress or egress in connection with the general system of conditions derived from observations at all other stations.

From the detailed reports of the two parties, given in the Appendices Nos. 13 and 14, it will be seen that in Japan the transit was observed with some measure of success. Unfortunately, clouds and rain prevailed at the critical hours on Chatham Island, and permitted little to be recorded bearing directly on the object of the expedition.

Assistant George Davidson, accompanied by Subassistant O. H. Tittmann and Mr. W. S. Edwards, aid in the Coast Survey, sailed from San Francisco on the 29th of August, and reached Yokohama on the 23d of September, 1874. Nagasaki, in Japan, having telegraphic communications with European observatories, was chosen by Mr. Davidson as the station for observing the transit. The astronomical instruments were mounted on a hill about one mile south of that city.

In advance of the period for final observations, the Japanese officials took deep interest in the subject, and detailed several intelligent Japanese to aid in the successive steps of the work. These subsequently reported to their government on the use of the instruments with which they had practice under the direction of Professor Davidson, and on the operations performed. Nagasaki connects by telegraph-cable to the north with Wladivostock, and to the south with the coast of China. Professor Hall, of the United States Naval Observatory, with a party at Wladivostock, by previous arrangement with Professor Davidson, exchanged several hundred clock-signals with the Coast Survey observers at Nagasaki on three favorable nights of October and November, and thus was carefully determined the difference of longitude between those two stations. The telegraph-station at Nagasaki was connected by triangulation with the point at which Mr. Davidson subsequently observed the transit of Venus.

Observations for latitude, others on the occultation of stars, and practice by the astronomical aids and photographers occupied the month preceding the 9th of December. On the 8th, good observations were recorded for local time, and another series for the same purpose was obtained early in the morning of the day on which the planet crossed the sun's disc. As these last observations were closing, clouds began to form and to thicken until sunrise. At the first contact of the planet, which Professor Davidson observed personally, the sun's limb was much obscured by clouds. The second contact was very satisfactorily observed by Professor Davidson and Mr. Tittmann, though the face of the sun was at the time covered by thin clouds and haze. After the first exterior contact, the clouds partially cleared, and micrometric measurements were made of the separation of the cusps of the planet. After the first interior contact, Professor Davidson secured, by micrometric measurement, records of the distance between the limbs of the sun and planet, and at the meridian-transits of the two bodies he observed the passages of their limbs for their difference in right ascension. His assistant, Mr. Tittmann, at the same time measured for their difference in declination by recording micrometer differences between the sun's upper limb and the upper and lower limb of the planet. Before culmination, and a few minutes after noon, Professor Davidson obtained a fine series of measures of the diameter of Venus under various degrees of brightness, using the double-image micrometer, the value of which had been previously determined by transits of the pole-star. Soon after, the face of the sun was again obscured, and no other observations seemed possible; but, fortunately, a momentary break occurred in the clouds, and the third contact of the planet was satisfactorily observed by Professor Davidson and also by Mr. Tittmann. Dense clouds shut out of view the fourth contact, and rain fell quickly afterward.

During the transit, the photographers attached to the party at Nagasaki exposed one hundred and sixteen plates, about half of them producing fair negatives. For clock-correction, a final set of star-transits was recorded on the evening of the 9th of December, the observations being made through breaks in the rain-clouds.

Between Professor Davidson and the officials of Japanese departments, cordial intercourse was maintained during the stay of the party in that empire.

In Section X of this report, mention will be made of subjects to which the attention of Mr. Davidson was given incidentally before his return to the United States.

Subassistant Edwin Smith, accompanied by Mr. A. H. Scott, aid in the Coast Survey, arrived at Whangaroa Bay, Chatham Island, in the United States ship Swatara, on the 19th of October, 1874. For determining the longitude of the place, the transit-instrument taken by the party was immediately mounted, and the chronometers were compared with the results obtained for local time.

Up to the 6th of December the weather continued fine at Chatham Island; the party was drilled in the use of instruments, and was in complete readiness for observing the transit of Venus. On the 7th, a storm set in, and prevailed while the planet was crossing the sun's disc. The first or outer contact was entirely hid by a cloud, but, through a momentary break soon after, a few cusp-measurements were recorded. The second or interior contact was also hid from view by clouds The sun shone faintly at intervals afterward, and a few measures with the equatorial were recorded. The photographers exposed twenty plates, all the points of which show the presence of clouds. Of the plates, about two-thirds will be of no value, in consequence of the cloudy obscuration of the sun.

From 5 o'clock p. m. till after the egress of the planet, rain fell, and no observation was practicable. Latitude was carefully determined at the observing-station on Chatham Island, and also the magnetic declination, dip, and intensity. The vicinity of the station was mapped by the party.

OBITUARIES.

During eight years preceding the untimely death of Prof. Joseph Winlock, director of the Cambridge observatory, on the 11th of June, 1875, the work of the Coast Survey had benefited by his resources and expedients in practical astronomy, and by personal co-operation in our most important longitude-determinations. At the observatory, his tenure was made effective to us by the activities of a strong intellect, that centered only on the attainment of desirable results. His extended list of Standard Time Stars is specially valuable. Amongst instrumental improvements and inventions resulting from his studies are the break-circuit chronometer and the horizontal photographic telescope, already in use for special purposes, and much valued by observers at home and abroad. That device was particularly serviceable in recording observations on the recent transit of Venus. Large prospective value attaches also to his labors in providing methods and means for precision in astronomical observations and records. Fortunately, studies to such ends were the bent of this able man of science, and so was he occupied on the last day of his life. In plan and effect, some of his ingenious devices have been realized to the advantage of science; of some, the application pertains to the future. The important results due to them will be gathered hereafter by other men.

Professor Winlock, though reserved to an unusual degree in manner and speech, was widely known. In the social circle, he was also warmly regarded. There his genial thoughts and feelings were quietly and evenly manifested toward all, and by all who knew him could be readily interpreted as the promptings of a fervent nature.

In the Engraving Division, the work of three skillful hands has been closed by death since the date of my last report. Of these, John Knight, who died on the 28th of November, 1874, had rendered thirty years of faithful service as engraver of titles and lettering on our principal charts. It will not be forgotten in the division that employment was his daily pleasure, a cast of mind which had early become habitual in this gentle, intelligent, conscientious man. Though not excelled as a letter-engraver, some of the last working-time of Mr. Knight was given to the application of forms for the improvement of style, and recently issued charts show that beyond the age of seventy-one years his hand retained its former skill. Only a few months after their completion, and in great debility, but without any apparent disease, he resigned life, exchanging in his last hour cheerful greetings and leave-takings with his relatives and many friends.

John C. Kondrup, Danish vice-consul for Washington City, joined the office as engraver in May, 1855, and, after continuous and acceptable service, died at his residence on Capitol Hill on the 10th of December, 1874. He was valued for skill in rendering the even outlines required on charts of the first order.

For some years, the health of Mr. Kondrup had been impaired by the pulmonary disorder that caused his death in his forty-sixth year. To the last, however, he manifested before all who silently grieved in view of the inevitable issue the same manly fortitude, friendly courtesy, and generous qualities of mind which at an early period had gained for him the esteem of a large circle in Washington.

Henry S. Barnard, an engraver of special talent in the branch of delineation known as "sanding" on charts, died, after a short illness, at the age of sixty years, on the 23d of September, 1874. As a worthy and industrious man, Mr. Barnard fulfilled the expectations which attended his call to the Engraving Division in April, 1856.

PART II.

In this part of the report, short abstracts, arranged in geographical order, will be given, to show the essential particulars of work done by each of the field and hydrographic parties. For the Atlantic coast, the order of arrangement will be from north to south, and, as heretofore, the work on the Pacific coast, will be noticed in the reverse order. The abstracts will be, as usual, recapitulated in tabular form, to accompany this report as Appendix No. 1. Widely distributed as the surveying parties have been off the coast and on the land, and subject to all the variations of weather and of climate between the West Indies and Alaska, it is gratifying to record that no serious accident within the year has been superadded to hardships that are in many places incident to the service. Much rough weather prevailed when parties were transferred last autumn for field-work and hydrography on the southern coast and in the Gulf of Mexico, but by cautious navigation all disasters were avoided. On the Atlantic side, some little delay was allowed in consequence of yellow fever, but the only seizure by pestilence occurred in a party on the Pacific coast. The sick hand, when small-pox appeared, was promptly removed to some distance, cared for properly by the chief of the party, and in due time was allowed to return, the work meanwhile not having intermitted.

In general, the notices of work done will be restricted to the mention of dates and limits, the names of the persons employed, and the results in statistics; but, in a few cases, collateral incidents, either of personal moment or of local interest, will also be mentioned.

For several months after the opening of the present year, I had the able co-operation of Capt. K. R. Breese, U. S. N., who accepted and effectively discharged the duties of hydrographic inspector in the Coast Survey until the end of May last. The intelligent interest, personal cordiality, and readiness of that officer in applying the results of matured experience in maritime details made it a matter of special regret to sever an association so promising for the future benefit of the Survey. In May, however, fortunately for the service, Commander Edward P. Lull succeeded in the vacant position, and to him I am already indebted for valuable assistance in providing for the transportation of field and hydrographic parties, and in other important details of the division, amongst which are plans, specifications, and estimates for the construction of vessels; arrangements for their repair and outfits; and, on the return of hydrographic parties, inspection of the manuscript charts in advance of their acceptance for registry and deposit in the archives. In general duties pertaining to the Hydrographic Division, including the selection of sailing-lines, preparation of notes for the engraved charts, and revision in regard to the marked positions of aids to navigation, Commander Lull is assisted by Lieut. H. E. Nichols, U. S. N.

Lieut. C. A. Bradbury, U. S. N., after service in the hydrographic party on board the steamer Blake, during the summer of 1874, off the coast of New England, was temporarily attached to this branch of the service. While he was at the office, exceptionally cold weather, after the opening of the present year, so much interrupted navigation along the eastern coast as to make a record desirable of peculiarities in the ice formation. At my request, he visited the ports of New England, and from pilots and others collected and recorded particulars at places near which ice was then regarded as dangerous to vessels in approaching the coast, and at others in which it had been or was then a hinderance to navigation. Inquiry was made also with reference to periods of recurrence in excessive ice formation; the dates at which navigation had been closed in preceding years; the effect of ice on sailing-courses here and there; and whether or not well-set buoys had been displaced by moving ice in the course of the winter.

As results of the investigation, it appears, from the detailed report of Lieutenant Bradbury, that the extensive local formations of ice in January broke up, and in the first week of February accumulated as drift-ice along the shores. Twelve days of severe cold followed, and in that period the local formations were renewed by ice, some of which remained in place until the middle of March. Meanwhile, the drift ice, by subsequent freezing, had formed extended masses, as in the lower parts of bays along the coast of Maine; also, in Cape Cod Bay; and as far to the southward as Long Island Sound the frozen drift was found in connection with ice, which remained where it

had formed. The movements of sailing-vessels were impeded, and navigation, except by powerful steam-vessels, was attended with danger in most of the sounds, bays, rivers, and harbors of the coast between Narragansett Bay and Eastport until the middle of March. On the coast of Maine, only a few of the buoys were displaced; but, as being more exposed to the sweep of large bodies of drift-ice, the displacement of buoys was general in Nantucket Sound, Vineyard Sound, Long Island Sound, Cape Cod Bay, Buzzard's Bay, and in the harbors adjacent. Lieutenant Bradbury's report was accompanied by a series of engraved charts, on which he indicated the extent of the local and casual ice formations in each of the localities. The unusual impediments recorded as affecting navigation seem to be due to the sudden cold that formed into fixed masses the ice which was liberated at the end of January. The substance of Lieutenant Bradbury's report will be embodied in the Coast Pilot.

SECTION I.

ATLANTIC COAST OF MAINE, NEW HAMPSHIRE, MASSACHUSETTS, AND RHODE ISLAND, INCLUDING SEAPORTS, BAYS, AND RIVERS.—(SKETCHES NOS. 2 AND 3.)

Deep-sea soundings.—At the end of June, 1874, Lieut. Commander John A. Howell, U. S. N., assistant in the Coast Survey, left Provincetown with his party in the steamer Blake, and was engaged until the middle of September in running offshore lines of soundings between George's Bank and the Bay of Fundy. In the latitude of Yarmouth, two lines were run across that bay, and one to the southward from Grand Manan Island. Further westward, several courses were steered, and soundings were recorded in crossing Jeffrey's Bank and Cashe's Ledge. The least depth found on that ledge was 7½ fathoms. Before the close of the season in this quarter, Lieut. Commander C. D. Sigsbee, U. S. N., who subsequently succeeded to the command of the Blake, joined the party with improved appliances and means for deep-sea soundings. These were put in operation by Lieutenant-Commander Howell, worked satisfactorily, and were subsequently used by the party in the Gulf of Mexico, of the work in which notice will be taken under the head of Section VIII. With the apparatus devised by Sir William Thomson for deep-sea soundings, and modified by Commander Belknap, U. S. N., the party on the steamer Blake readily brought up specimens of bottom from a depth of 2,144 fathoms in the Gulf of Maine. The work in the steamer Blake was prosecuted with the assistance of Lieutenants W. H. Jacques, E. S. Jacob, Richard Rush, and C. A. Bradbury, U. S. N. At the end of the season in this section, the first three of these officers, who had rendered acceptable service during several preceding seasons, were detached from the Coast Survey. The statistics in deep-sea hydrography of the Gulf of Maine are:

Miles run in sounding	3,491
Positions determined	110
Number of soundings plotted	531

Commander Howell, at my request, kindly retained charge of the steamer Blake until after the arrival of the vessel at New Orleans, and the organization of a party for hydrographic work in the Gulf of Mexico. After the close of the season in that section, in June last, Lieutenant-Commander Sigsbee returned with the steamer Blake to the coast of New England, and will prosecute the offshore hydrography until November of the present year. The term of service of Commander Howell on Coast Survey duty was closed by his assignment by the Navy Department to the responsible position of instructor of gunnery at the Naval Academy, Annapolis.

Topography and hydrography, Mount Desert Island, Me.—Resuming field-work in this section at Hull's Cove in July, 1874, Assistant J. W. Donn traced the remaining shore-line of the northwestern part of Mount Desert Island, and joined with the limits of a previous plane-table sheet at Pretty Marsh Harbor. The interior topography was then filled in to join the limits of topography completed in other seasons. North of the Mount Desert Narrows, the shores were traced to include Eastern Bay, Western Bay; the island shores in that vicinity; and further to the southward the islands in Bartlett's Narrows.

With his party in the schooner Scoresby, Mr. Donn took up the hydrography in the vicinity of Sands Point, where the operations had been closed in the preceding year. The soundings develop the depths in Bartlett's Narrows and Mount Desert Narrows, and include Clark's Cove, Salisbury Cove, and Pretty Marsh Harbor. The head of Placentia Bay was also sounded for some distance from the shore; but, the water being deep in the body of that bay, its general hydrography will be prosecuted with means which were not available when the plane-table work was in progress.

The work done by the party of Assistant Donn completes the detailed survey of Mount Desert Island. He was aided in the field by Messrs F. C. Donn and F. H. Parsons. The following summary shows the statistics of work:

Shore-line surveyed, miles	69
Creeks and ponds, miles	38
Roads, miles	49
Area of topography, square miles	41½
Miles run in sounding	443
Angles measured	3,967
Number of soundings	18,293

Egg Rock, in Frenchman's Bay.—With reference to its fitness for the location of a light-house Assistant Donn made a special survey of this rock, under my direction, in August, 1874. The surface was carefully mapped on a large scale to show successive elevations of six feet. Mr. F. C. Donn, the aid, after careful examination by trial with a boat, marked on the sheet of survey the points at which, under ordinary circumstances, landings might be effected. During heavy gales, it is not possible to land a boat anywhere at the rock in safety.

The work in this section occupied the party of Assistant Donn until near the end of October, 1874, when preparation was made for resuming operations in Section III, under which head mention will be made of the work done during the winter.

Topography of Eggemoggin Reach, Me.—The plane-table survey of the coast of Maine, in the vicinity of Eggemoggin Reach, was resumed by Assistant W. H. Dennis on the 17th of June, 1874. After completing work to include the northern part of Deer Isle, the party was transferred to the opposite shore of the reach, where a fringe of the usual width in topography was mapped from Sedgwick southward and eastward to Naskeag Point and from thence northward to the mouth of Blue Hill Bay. The shores of Herrick's Bay are shown on one of the three plane-table sheets which were worked on in the course of the season, as are also the islands, rocks, and ledges that exist within the working limits of the season. In character, the topography is that generally seen on this part of the coast, a rocky, irregular shore-line, backed by ground unevenly hilly, and marked by considerable detail in natural features and artificial improvements. Mr. S. N. Ogden and Mr. W. S. Bond served as aids. The work was closed on the 30th of September. A synopsis in the field-report shows as statistics:

Shore-line surveyed, miles	31
Roads, miles	50½
Area of topography, square miles	26

The subsequent occupation of Assistant Dennis will be stated under Section V in this report.

Hydrography of Eggemoggin Reach, Me.—In the latter part of September, 1874, after the completion of work which will be stated pre-ently, Assistant Horace Anderson, with his party, in the schooner Silliman and steam-launch Sagadahoc, sounded out the western part of Eggemoggin Reach. In the adjustment for plotting the chart, the work was referred to a tide-gauge, which was used for recording at Sedgwick while the hydrography was in progress.

Master Kossuth Niles, U. S. N., joined the party in the Silliman at the opening of the season in this section, and after the close of work acceptably conducted the operations of a hydrographic party in the same vessel, as will be mentioned under the head of Section VII in this report.

Assistant Anderson was aided on the coast of Maine by Mr. F. H. North. Both were subsequently employed in southern sections.

The following aggregates include the hydrographic work in Eggemoggin Reach and that done at several detached localities in the Penobscot:

Miles run in sounding	278
Angles measured	3,450
Number of soundings	22,406

On closing work early in October, the steam-launch was laid up at Cousin's Island in Casco Bay. The schooner Silliman was soon after refitted for service in the Gulf of Mexico.

Topography of islands in Penobscot Bay, Me.—For the survey of numerous small islands, some lying south of Cape Rosier, others westward of Deer Island, and some in the vicinity of Isle au Haut, a party was sent in the schooner Caswell early in July, 1874, under charge of Subassistant J. N. McClintock. After completing the details about Cape Rosier and near the Fox Islands, Mr. McClintock mapped the islands southwest of Mark Island light-house, and subsequently Marshall's Island and smaller ones between it and Isle au Haut. The details on the several sheets include all the rocks and ledges visible at low water. In the vicinity of Spruce Head, the party mapped Pickering's Island, Bradbury's, Eagle Island, Pond Island, and many others of less area. Before closing work at the end of September, Subassistant McClintock determined in position the lights at Burnt Coat Harbor. The topographical statistics are:

Shore-line traced, miles	31½
Roads, miles	5
Area of topography, square miles	4

The sheets containing this work show one hundred and seventeen islands and ledges. Messrs. T. A. Harrison and W. Fraser were attached to the party as aids.

Topography above Castine, Me.—The party of Assistant A. W. Longfellow, in the schooner Joseph Henry, resumed field-work near Castine on the 11th of July, 1874, and closed operations for the season on the 8th of October. On the resulting topographical sheet are represented the entire vicinity of Castine and the southwest part of the town of Penobscot, the east shore of Penobscot Bay as far up as Morse's Cove, where the work of this party joins with that of Subassistant Hergesheimer, and the north side of Bagaduce River to a point opposite to Morse's Cove. The site of the old English Fort George and remains of seven batteries, constructed probably at the earliest period in the history of New England, were carefully marked on the plane-table sheet by Assistant Longfellow. Mr. W. C. Hodgkins was attached to the party as aid. At the close of work, the vessel, as being no longer seaworthy, was laid up in Casco Bay. The following are statistics of the plane-table survey:

Shore-line surveyed, miles	20
Streams, miles	26
Roads, miles	18
Area of topography, square miles	13

The sheet represents the shore-lines at high water and at low water, and, besides details of surface, successive elevations of twenty feet for the entire area included within the survey.

Topography near Bucksport, Me.—North of the work mentioned under the last head, Subassistant Joseph Hergesheimer completed the detailed survey of the east side of Penobscot Bay, to include the towns of Bucksport and Orland, Whitmore's Island, and the shores of Eastern Penobscot River, in the vicinity of the towns named. At both places, the outlines of the wharves were also traced, and appear on the upper plane-table sheet as part of the details of survey. Mr. Hergesheimer extended work about eleven miles north of the line at which his survey joins with that of Assistant Longfellow. As the operations advanced, tracings from the shore-line survey were furnished for the use of the hydrographic party. Field-work in this section was begun by Mr. Hergesheimer late in June, 1874, and was continued until the middle of October. His subsequent

service will be stated under the head of Section VI in this report. The statistics of work on the two plane-table sheets, showing the features below Bucksport, are:

Shore-line, high water, miles	34
Shore-line, low water, miles	26½
Roads, miles	27
Area of topography, square miles	19

Mr. Hergesheimer is now making arrangements for resuming field-work near Tampa, Fla.

Topography of Bagaduce River, Me.—This works connects with that mentioned under the two preceding heads. For extending the survey eastward of Castine Harbor, Assistant Hull Adams commenced early in July, 1874, at the entrance of Bagaduce River, and traced its shores, to include the expansion known as South Bay, the islands which separate that expanse from North Bay, and the branch of the river which includes Johnson's Narrows. All the roads in the vicinity of the water-line appear on the topographical sheet, and the village of West Brookville. Contour-lines to show the character of the surface were traced as usual. Signals were set up by Mr. Adams for extending the plane-table survey as far south as Walker's Pond, but the advance of the season made it expedient to close work in the middle of October, and to defer the completion of the second sheet. The statistics are:

Shore-line surveyed, miles	25½
Roads, miles	20½
Area of topography, square miles	20

Assistant Adams was aided in this survey by Mr. R. B. Palfrey. His party is now at work on the shores of the river beyond the limits of the work here noticed.

Hydrography of Penobscot Bay.—Early in July, 1874, the schooner Silliman, with the party of Assistant Anderson, left Portland to prosecute soundings at several localities near Penobscot Entrance. The numerous ledges between Cape Rosier and the Fox Islands were developed. In August, Mr. Anderson found, south of Isleboro', and sounded out, a shoal on which the revenue-cutter Dobbin had grounded. In Penobscot River, soundings were extended upward as far as Winterport. Assistant Anderson remarks of that part of the river that a *middle ground* is forming opposite to Fort Knox. Several ledges in Belfast Bay were developed by soundings. The work between Cape Rosier and the Fox Islands was referred to a tide-gauge at Castine; that in the Penobscot to a tide-gauge on the steamboat-wharf at Bucksport. The statistics of the hydrography here noticed are included in the synopsis given under the head of Eggemoggin Reach in a preceding abstract in this section.

Tidal observations.—The series begun at North Haven (Penobscot Entrance, Me.) in January, 1870, has been well maintained through the fiscal year by Mr. J. G. Spaulding. As stated in my last report, the self-registering gauge at that station is furnished with all requirements for the preservation of a continuous record. Among these is the apparatus for heating, which proved effective last winter, no tides being lost even when the cold was excessive. Occasionally, when the gauge, is stopped for repairs, Mr. Spaulding has continued the record by staff-observations, so that from the beginning of the series each high and each low water is given in the record.

Co-efficient of refraction.—The party of Assistant F. W. Perkins was ready for work at Ragged Mountain, a station of the primary triangulation near Camden, Me., in the middle of July, 1874, but operations were hindered for several weeks by fog, haze, and rain. During that interval, however, as throughout the season, the requisite meteorological observations were recorded hourly on the mountain, and for periods of ten days each at Mount Desert and White Head light-house. The heights above tide-water of the geodetic stations on Ragged Mountain and Mount Desert, of a point on Tennant's Harbor, and of the light-houses at White Head, Owl's Head, and Matinicus were determined by lines of levels run by the aids of the party, Messrs. C. L. Gardner and F. W. Ring.

Before commencing observations with the barometer, psychrometer, and thermometer for determining the co-efficient of refraction, the instruments were carefully compared with standards.

One series of observations, recorded at Ragged Mountain, included hourly measurements of the vertical angles made by lines from the signals on outlying stations, the distances to which were known. The absolute height of each of the stations as measured by the aids completed the records for computation. Mr. Perkins closed work on the 1st of September, and later in the season resumed the survey of the Gulf coast in Section VII.

Triangulation in New Hampshire.—Early in June, 1874, Prof. E. T. Quimby took the field, and by reconnaissance determined the practicability of a scheme of triangulation to pass from the valley of Connecticut River, or western boundary of New Hampshire, westward to the Green Mountains. The detailed work was then taken up at Observatory Hill near Hanover, N. H., a station in the system which connects with the primary triangulation of the coast of New England. Azimuth was determined at Observatory Hill, and Dartmouth College observatory was connected with that station by the measurement of horizontal angles. Kearsarge Mountain was occupied with the theodolite early in July, 1874, and Cube Mountain before the end of that month. The observations were continued at all favorable intervals until the close of the season in August. Statistics of the field-work are thus stated in the report of Professor Quimby:

Stations occupied	3
Points determined	70
Number of observations	4,088

At all the stations occupied, as many subsidiary points as could be identified were observed on. By such means, many objects are determined approximately in position, and noted in the record as data for the construction of a map of the State.

Professor Quimby again took the field on the 1st of June, 1875, commencing the operations of the season at Croydon Mountain. The details of work done in the course of the present fiscal year will appear in my next annual report.

Isles of Shoals.—The hydrographic party of Acting Master Robert Platt, U. S. N., in the steamer Bache, was in readiness for duty in this section in the middle of July, 1874, having made final preparations for work while at anchor in the harbor at Isles of Shoals. In steaming out by the channel between Half Way Rock and Star Island, the vessel passed very near to a rock, which was found, on examination, to have only seven feet of water on it at low tide. Notice was promptly given of the existence of this danger, and, at intervals when weather was unfavorable for offshore work, the vicinity of the rock and of the ledges adjacent to the islands was carefully sounded. The chart has been revised in accordance with the results of this examination, amongst which is a development of the channel between Star Island and Cedar Island, showing a depth of only nine feet at mean low water.

Jeffrey's Ledge.—Acting Master Platt sounded out this ledge in August, and found no depth less than has been heretofore reported. Working, however, with a steam-vessel, and under circumstances otherwise favorable, the contour of the ledge was defined with greater accuracy than has been hitherto practicable. The chart was plotted from records which showed the angles taken simultaneously by theodolite-observations from White Island light-house, and by the sextant while soundings were in progress.

Cashe's Ledge.—In reference to his work in that vicinity, Acting Master Platt reports as follows: "The deep-sea lines running off to the ledge depend of necessity on the logs and chronometer-observations, our departure being always from shore points which had been well determined The direction of the ship was followed by sextant-angles on the different light-houses, and the end. of each line was determined as carefully as possible by taking angles and bearings on prominent objects as soon as they became visible."

The soundings recorded by the party on the steamer Bache showed no depth on Cashe's Ledge less than twenty-four fathoms; but, as the existence of less water is not at all doubtful, it seems probable that future soundings may develop spots having as little as seven fathoms between the lines of soundings recorded in this examination.

Platt Bank.—Outside of the curve of 100 fathoms, and between Jeffrey's Ledge and Cashe's Ledge, Acting Master Platt found a bank the existence of which was hitherto unknown. He reports that, unlike most of the shoals in this section, the soundings showed it to be composed of

sand, gravel, and broken shells, but without any mud. The bank was carefully developed, and proved to be about 10 miles long east and west, and 5 miles in breadth, within the curve of 50 fathoms. The least water on Platt Bank found in the survey here noticed was 29 fathoms. Specimens of the dredgings taken while soundings were in progress were forwarded to Dr. A. S. Packard as having probably some bearing on the researches now pending under the direction of Prof. Spencer F. Baird, United States Commissioner of Fish and Fisheries.

Jeffrey's Bank.—This bank was reached in the hydrographic operations by deep-sea lines started from well-determined points on shore. Acting Master Platt found the bottom very irregular, but the general depth as developed by the soundings does not vary from the depth heretofore reported.

Early in September, Dr. Packard and two assistants were taken on board of the steamer Bache at Salem, and the next fortnight was passed in dredging and in instrumental tests on sea-water. Specimens of sea-bottom taken at forty different localities were procured in that interval by the observers. Temperatures of the water were recorded at sixty-three positions in the course of the operations on the several banks and ledges. The general statistics of the work are:

Miles run in sounding	833
Angles determined	678
Number of soundings	2,690

Late in October, the steamer returned to Norfolk, and was there refitted for hydrographic service, of which mention will be made in Section VI of this report.

Mr. J. B. Adamson was attached as aid to the hydrographic party on board the steamer Bache.

Tidal observations.—At Boston navy-yard, the self-registering tide-gauge of the old form, although provided with heating apparatus, became clogged with ice during the severely cold weather of last winter. Several breaks in consequence appear in the tidal records. The observer, Mr. H. Howland, reports that ice formed in a large mass around the float-box. This seems to have been a consequence of the accumulation of mud, and resulting want of depth in the water around the lower part of the box. The apparatus will be refitted for service at this station.

Hydrography westward of Monomoy, Mass.—With his party in the steamer Endeavor, Subassistant F. D. Granger resumed work near Monomoy on the 10th of July, 1874. Soundings were prosecuted to include, in the northern part of Nantucket Sound, part of Handkerchief Shoal, Chatham Roads, and generally the waters westward to the vicinity of Bishop and Clerk's light-house. Along the north shore of the sound, a space was not reached in the operations previous to the date at which it was most expedient to withdraw the vessel for service during the winter in Section VI. The space referred to was therefore included in plans of work to be prosecuted in the autumn of 1875. Much bad weather was experienced in the summer of 1874. The work in deep water was frequently interrupted, and boat-work was impracticable during the stay of the party. Hydrographic operations were discontinued for the season on the 20th of October.

Tidal observations were recorded during three months at Monomoy, and for part of the season also at Hyannis.

On a separate hydrographic sheet, Subassistant Granger plotted soundings which were made by his party at favorable intervals in the vicinity of Nantucket light-house, to develop the present character of Great Point Rip, and to fill a space near it and farther eastward. The aggregate statistics of work are:

Miles run in sounding	701
Angles measured	5,649
Number of soundings	28,685

Soon after the inception of this work, Lieut. R. D. Hitchcock, U. S. N., joined the party in the steamer Endeavor, and assisted in various details pertaining to the hydrographic survey. At the close of the season, he took charge of the vessel, and prosecuted work of which notice will be taken under the head of Section VI.

Subassistant Granger was aided in the work near Monomoy by Mr. D. C. Hanson.

Survey of Taunton River, Mass.—For the determination of points on which to found the plane-table survey of the shores of Taunton River, Assistant A. M. Harrison took the field on the 15th of July, 1874. The triangulation was joined with stations previously occupied on the shores of Mount Hope Bay, and was extended about twenty-two miles upward along the course of the river. Rapid advance in local improvement, the extension of city-limits, and the opening of new roads had, by consequent alterations of the ground-surface, displaced the station-marks in the vicinity of Fall River, which positions were relied on at the outset of the season for a prompt beginning in plane-table work. Points were determined, however, sufficient in number for a topographical sheet, by the 20th of September, when Mr. Harrison commenced the plane-table survey at a station about three miles above the mouth of the river. The triangulation was continued a month beyond that date, in charge of Mr. W. H. Stearns, one of the aids in the party.

On the topographical sheet, which was completed by the 6th of November, details of survey were shown for both banks of the river from points below Steep Brook Village, to stations above Somerset. The features generally within about one-third of a mile from the water-line are included in the survey. In joining with the limits of work done in 1861, Mr. Harrison noticed that great alterations had been wrought in the interval, not only in respect of artificial features, but also in regard to the shore lines. The completed sheet represents the town of Somerset, and the villages of Steep Brook, Pottersville, and Egypt, the Old Colony and Newport Railroad, with deep cuttings and high embankments, its course across the river, and the high embankment opposite to Somerset. Above that town, the points already determined will suffice for extending the plane-table survey to the vicinity of Taunton.

Assistant Harrison was aided in the topographical survey by Mr. Bion Bradbury. In the survey here noticed, the amount of detail relative to the area represented is unusually large, hence the general statistics, as reported at the end of the season, do not properly measure the degree of labor requisite for the results. The statistics are:

Signals erected	33
Stations occupied	32
Points determined	44
Observations with theodolite	7,008
Shore-line surveyed, miles	16
Roads, miles	29
Creeks, ponds, and marsh, miles	11½
Area of topography, square miles	2¼

Assistant Harrison is now at work on Taunton River some miles above Somerset.

Physical survey of Providence Harbor, R. I.—This work, prosecuted during the autumn of 1874 in connection with a careful shore-line survey, was undertaken at the request of the city authorities of Providence. All the running expenses of the two parties engaged under the direction of Assistants H. L. Whiting and Henry Mitchell were defrayed by the municipal government.

The question presented in the call for this special survey, as made known by previous conference with the chairman of the harbor commissioners, W. W. Rickard, esq., is expected to result in the assignment of limits in encroachments upon the harbor and its tributary basins, or lines beyond which the water-space could not be encroached on without injuriously affecting the natural order of its tidal and river streams that maintain the present channels. Anchorage, of course, and winding-room, in present use, or likely to be required hereafter by vessels visiting the port and wharves of the city, necessarily make parts of the question involved. As a basis for the special hydrography, Assistant Whiting carefully traced the shores of Providence Harbor and Seekonk River, and subsequently mapped the results in triplicate. Two of the sheets represent the results of the physical survey, and on two others the proposed lines as limits of encroachment are traced. The six sheets on a scale ample for any future purposes of the city authorities were delivered to the harbor commissioners in March last.

For the special hydrographic work, the party of Assistant Mitchell left New York in the schooner Research on the 3d of September, and, without delay, took up soundings and continued observations on the currents of Providence Harbor until the 12th of October. The results appear

on two of the sheets already mentioned as isodynamic lines and transverse curves of currents. The soundings were carefully plotted, and represent the hydrography of the harbor below the bridges. These details and the tidal and current observations were conducted under the immediate direction of Mr. Mitchell by Assistant H. L. Marindin. Mr. J. B. Weir served as aid in the hydrographic party. The following is a synopsis of statistics:

Angles measured	1,630
Number of soundings	8,910
Observations on currents	5,474

While the work was in progress in Providence Harbor, Mr. Mitchell, as associate member of the board of engineers on the improvement of the Mississippi outlets, was called away for conference relative to that service, further mention of which will be made under the head of Section VIII.

Tidal observations.—The city engineer who commenced the series of observations at Providence, R. I., has been furnished with a supply of paper for continuing the record by means of the self-registering tide-gauge. This series, if well maintained, will in time be useful for the investigation of tides in Narragansett Bay.

Pendulum observations.—The series of observations commenced last year was continued during the present season at Hoosac Mountain, near North Adams, Mass., by Assistant C. S. Peirce, under the general direction of the consulting geometer of the survey, Prof. Benjamin Peirce. Other stations will be occupied in order to procure means for investigating the laws of variation in the intensity of gravity, and thus to aid in determining the figure of the earth. The fact will be kept in view that in many places gravitation has been found at the sea-level on islands, greater than on mountains far from the sea. Assistant Peirce was aided in the observations at North Adams by Mr. W. E. McClintock.

Under sanction from the Treasury Department, Mr. Peirce proceeded in April last, in accordance with my instructions, to repeat experiments at various stations in Europe. The objects sought are, to compare, by swinging at the foreign stations the non-invertible pendulum and the invertible pendulum belonging to the Coast Survey, with pendulums used in the geodetic operations of the great European surveys. This work is yet in progress, and will include all the tests needful for determining relations between our own and the foreign instruments which have been heretofore used for ascertaining the force of gravity and of local attraction. The results of the work will be given in my next annual report.

SECTION II.

ATLANTIC COAST AND SEAPORTS OF CONNECTICUT, NEW YORK, NEW JERSEY, PENNSYLVANIA, AND DELAWARE, INCLUDING BAYS AND RIVERS.—(SKETCHES NOS. 4 AND 5.)

Survey of Thames River, Conn.—For continuing the survey of the Thames above the naval station, a party was organized on the 8th of July, 1874, and prosecuted work in the field, under the charge of Assistant H. G. Ogden, until the 2d of October.

In order to provide points for the plane-table work, Mr. Ogden extended a tertiary triangulation from the vicinity of the naval station upward along the course of the river to Norwich. The topographical survey was resumed at points above Gales' Ferry, and was continued along both sides of the Thames as far up as the junction of the Shetucket with Yantic River. Parts of both of these streams appear on the hydrographic sheet, which contains also the soundings made in the Thames between Norwich and the naval station.

The topography of this season joins previous work on the east bank at a point sometimes designated as Mount Decatur, and embraces a strip about half a mile wide to within one mile of Norwich, but is restricted to the river road in approaching the city. On the west bank, the survey by Mr. Ogden was begun at Mohican, and includes the tract between the river and the New London turnpike from Mohican to the vicinity of Norwich, narrowing near the suburbs. Tides were observed with a gauge near the naval station, and also at a wharf near Norwich. It is noted in his report by Assistant Ogden that the records of observations steadily indicated a rise and fall at the city

six inches greater than the rise and fall of tide at the naval station. Mr. Ogden mentions his obligation to Rear-Admiral Reed Werden, then commandant at the naval station, for the use of a boat for hydrographic work. The statistics are as follows:

Signals erected	17
Stations occupied	14
Points determined	40
Shore-line traced, miles	49
Creeks and marsh, miles	8½
Roads, miles	37½
Area, square miles	11
Miles run in sounding	94
Angles measured	737
Casts of the lead	8,937

Mr. D. B. Wainwright aided in the field-work and hydrography. The work subsequently done by the party of Assistant Ogden will be noticed under the head of Section VI.

Survey of New Haven Harbor, Conn.—The work of Assistant R. M. Bache in the survey at New Haven has resulted in the completion of thirteen plane-table sheets, showing the details of topography along the shores above Oyster Point and Fort Hale. During July and August, 1874, and under his immediate direction, the survey was continued above New Haven by a party of volunteers from the Sheffield Scientific School, and, until November, by two others, maintained at the expense of the city, for mapping details desired by the harbor commission. Mr. E. C. Savage, graduate of the Scientific School, conducted one of the parties, the members of which had been instructed in the use of the water-level on the plain near the city. In progress eastward, contour-lines were traced in as the party ascended the range of hills in that direction. The details are full in relation to the area, the ground passed over being largely covered by extensions from the former limits of the city. Twenty-four miles of roads and streets, and all artificial improvements in that quarter, appear on the topographical sheet. The two working-parties furnished by the city were conducted by Messrs. Horace Andrews and Neville B. Craig, both graduates of the Scientific School. Seven large sheets, each three feet square, having been completed in the preceding season, the parties took in hand field-work for the eighth, and closed after completing the thirteenth sheet. The ground features and artificial objects were mapped with great precision, on a large scale, on drawing-paper attached, in the manufacture, to thin metallic plates, by a special process developed by Assistant Bache. Twenty-one miles of water-line were minutely traced for the five sheets. The adjustment of these and other features required the determination of twenty-two additional points by triangulation, and the measurement of sixty-eight horizontal angles.

Additional to the work already noticed, Assistant Bache made a special survey of Drummond's Bank in the Quinnipiac, and closely determined the differences in depth, to enable the harbor commission to decide on exceptions which had been filed against the line marked as a harbor limit. In this survey, each sounding was located by an angle measured by simultaneous determinations with two transits. For the adjustment of soundings in the harbor, special care was taken in the establishment of a bench-mark and in recording the tides.

In the course of the winter and spring, the large amount of details mapped in the field in pencil was inked, and the sheets have been delivered to the harbor commission.

Triangulation, Long Island Sound, N. Y.—Near the end of July, 1874, Assistant J. A. Sullivan took the field in this section, in order to co-operate with Assistant Cutts for the triangulation near the boundary between Connecticut and New York. In the course of a week, Mr. Sullivan put up signals at Wooster, Mount Tom, and Good Hill stations, but on an emergency he was then transferred to the eastern end of Long Island Sound, and was there engaged until the 1st of December. Thirteen light-houses were determined in position. These include the old and the new structure on Block Island, and those at Montauk, Mystic, Race Point, North Hummock, Gull Island, Cedar Island, Plum Island, Long Beach, Gardiner's Island, Faulkner's Island, Ponquogue, and the derrick which gives an approximate center for the foundation of a light-house under construction at Race Rock, near the west end of Fisher's Island. The beacon in Plum Gut was also determined in

position. The triangulation done in this vicinity availed for the uses of the hydrographic party, the operations of which will be mentioned presently. In order to complete the determinations of position, it will be requisite to occupy additional stations, and, in July of the present year, Assistant Sullivan will take the field for that service. The statistics of the work done in the autumn of 1874 are:

Signals erected	15
Stations occupied	8
Number of angular measurements	2,584

At the outset of the season, and until a small vessel could be hired, this work was favored by the courtesy of F. H. Stott, esq., vice-commodore of the Brooklyn Yacht Club, who was then cruising in the vicinity. In the course of several weeks, the party was transferred from station to station by that gentleman in his own yacht; the aid being, moreover, made specially acceptable by the earnestness of Mr. Stott in repeating his invitations, and by his cordial expressions of interest in the work of the party.

Hydrography near Plum Island, Long Island Sound, N. Y.—Soundings which have heretofore appeared on the published chart of this part of Long Island Sound were made in the year 1838, and the vicinity has not been subsequently examined until within the present surveying year. In July, 1874, my attention was asked for the development, by special soundings, of the channel which leads west of Plum Island from Gardiner's Bay into Long Island Sound. As soon as practicable, the work was taken up by Assistant J. S. Bradford, who completed the hydrography of the entire channel between Oyster Pond Point and the west end of Plum Island. His party, in the schooner Palinurus, was engaged in this work until the 21st of August, 1874.

A few days after, Capt. K. R. Breese, U. S. N., then cruising with the United States ship Constellation, reported that his ship had touched on a rock or shoal between Gull Island and the entrance to Gardiner's Bay. Assistant Bradford, being near by, commenced search immediately, but many traverses were patiently run in the course of seven days before any rock was found on which a deep-draught vessel could have touched. A spar-buoy was placed by the party in the Palinurus to mark the danger. Amongst the expedients for finding such rocks, Mr. Bradford used a sweep, weighted in the usual manner, and which, in operation, made it plain that some of the many rocks in that locality are large bowlders that merely rest on the bottom near the eastern end of Long Island, and that the rocks may be easily overturned. The drag used having 70 fathoms of line, and towed by the gig and cutter, finally caught on a large bowlder, the depth on which was found to be 23 feet at mean low water, the depth around it being 5 fathoms, as was found when the Constellation touched. The ship, however, was drawing not more than 21 feet, and her position was well determined. Hence, although from observation, in regard to other bowlders in the vicinity, it might be inferred that the Constellation, on touching, overturned a rock, many of the bowlders having been overthrown in the search by a force not comparable with the impact of a large ship, the difference in positions makes it plain that the rock found by Mr. Bradford is not the bowlder which was struck by the Constellation. The search for that rock will be renewed, and it will doubtless be identified. When the chart of this vicinity was issued some years ago, the requirements in graphical hydrography were not such as they are now. In order that the close supplementary sounding made by the party in the Palinurus might avail at once for the engraved chart, positions on shore in the vicinity were carefully determined by the triangulation-party of Assistant Sullivan.

Before resuming the work to which his party had been assigned for the season, Assistant Bradford made a survey of the "East Ground" off Block Island and found 7 fathoms. This shoal lies about five and a-half miles eastward of Block Island, and by a passing vessel had been reported as having shoaled to 6 fathoms. After completing the reconnaissance, a survey was made of Block Island Basin, the breakwater constructed by the United States engineers being then nearly finished. The following shows the statistics of work done near Plum Island:

Miles run in sounding	58
Angles measured	1,054
Number of soundings	3,888

The resulting hydrographic sheet shows Beebe Rock with only 8 feet of water on it, near North West Point, and a shoal with 17 feet about midway between Pine Point and the spindle on Oyster Pond Reef. In reference to alterations along the shore, Assistant Bradford says: "Oyster Pond Point and the west shore of Plum Island have changed very much and are rapidly being cut away. At the northwest point, the light-house site is defended by lines of heavy bowlders, that, falling, when washed out by the action of the water, now form a natural breakwater, which protects the face of the cliff. What was formerly Oyster Pond Point is now a mass of bowlders with threads of water between them; but, where there are no bowlders, the point is gradually giving way."

Coast Pilot.—The work noticed under the last head was done at intervals of the time allotted between June and December for compiling notes for a second volume of the Atlantic Coast Pilot. In previous years, Assistant Bradford had personally examined all the harbors between Eastport and Point Judith. The larger part of his notes gathered in that work were printed last year, giving descriptions of dangers and sailing-directions for entering the harbors of the coast of New England north of Boston.

Assistant Bradford, in the schooner Palinurus, resumed the special examinations in July, 1874, and in the course of the summer and autumn prepared descriptions and notes relative to Long Island Sound, Block Island Sound, and Fisher's Island Sound; and of the harbors of Stonington, New London, Saybrook, New Haven, Napeague Bay and Gardiner's Bay, Greenport, Peconic Bay, Hempstead, Oyster Bay, Huntington Bay, Bridgeport, and Black Rock; the harbors at Sheffield Island, Cawkins Island, Captain's Island, Sachem Head, Hart and City Islands; the passage through the sound at Hell Gate; the courses of navigation in the waters of New York Bay; and notes respecting Newark Bay, Elizabethport, Perth Amboy, and the south coast of Long Island. The vessel and party were engaged in this service until the 20th of November, when the Palinurus returned to Norfolk and was laid up for the winter.

Mr. Bradford was aided throughout the season by Mr. J. R. Barker, whose skill in graphic representation is well illustrated by the sixteen views, taken from the deck of the Palinurus, of approaches and harbor-entrances that are mentioned in the notes of the year. In March last, after adapting, for a cheap and effective process of reproduction, the series of views drawn by the late W. B. McMurtrie, as illustrations in a final edition of the first volume of the Coast Pilot, Mr. Barker etched the views on glass preparatory to their transfer to stone for printing. Assistant Bradford occupied the winter in compiling and arranging notes for the second volume of the Coast Pilot, the preparation of which is now well advanced. During the summer and autumn of the present year, Lieut. C. A. Bradbury, U. S. N., will be associated with the party on board the schooner Palinurus, for revising work in advance of a second edition of the Coast Pilot.

Survey of Port Jefferson, Long Island, N. Y.—The party of Assistant F. H. Gerdes was organized for service with the schooner Dana, and early in July, 1874, was at work in the vicinity of Staten Island. For determining in position the new light-house near Fort Tompkins, a short base was measured, and connected with several triangles that were laid out between it and the position of the fort. Azimuth was determined for the line joining one of the stations with Trinity spire, the relative place of which, in the triangulation of New York Harbor, was previously well known. On the completion of this work, the party was transferred to Port Jefferson, on the north side of Long Island. Mr. Gerdes identified two of the stations which had been occupied for the triangulation of Long Island Sound. From these, points were determined sufficient for a plane-table survey, which was made in the course of the season to include Port Jefferson, Setauket Harbor, and Conscience Bay. The waters included within the topographical limits were sounded carefully. Outside of the entrance, the hydrography was extended about a mile beyond the shore, and close soundings between Oldfield light-house and Mount Misery were plotted on a separate sheet. Subassistant C. P. Dillaway was attached to the party in the schooner Dana. The statistics of the work are:

Shore-line surveyed, miles	21
Roads, miles	9
Area of topography, square miles	7
Miles run in sounding	115
Angles measured	1,055
Number of soundings	12,104

The survey of Port Jefferson was completed on the 4th of October. A few days after, the party engaged in work which will be mentioned presently in this section.

Triangulation.—The New York boundary-triangulation, commenced by the late Edmund Blunt, assistant in the Coast Survey, for determining the exact geographical position of monuments on the line between that State and Connecticut and Massachusetts, starts from a line of the primary triangulation at Tashua and Ivy Stations, and ends at the line joining Perry's Peak and Yellow Pine Stations, near the parallel of Castleton. For extending this scheme northward, and thus connect the survey of Lake Champlain with the primary series, and also provide a basis for meeting prospective requirements in regard to the determination of points in the interior, Assistant Richard D. Cutts took the field at the end of June, 1874, and first occupied Perry's Peak, a point very little eastward of the boundary-line between Massachusetts and New York. As soon as practicable, signals were erected by his aid, Mr. J. F. Pratt, on Greylock, on Yellow Pine Station, and on Mount Rafinesque, but, owing to a succession of rainstorms, angular measurements with the theodolite were not completed at Perry's Peak until the 18th of August. The party was immediately transferred to Yellow Pine, where the requisite observations were closed on the 21st of September. A few days after, the instruments were in position on Mount Rafinesque. The summit was cleared to afford an open horizon, and Mr. Pratt was detached to set up signals at the outlying stations. By the 8th of October, observations to the southward and westward were complete, but the signals on Mount Equinox, Greenwich, and Corinth Hills, which, by reason of distance, could be seen only under circumstances exceptionally favorable, were entirely hidden from view after the 20th by the haze of Indian summer. On the 23d of October, Assistant Cutts closed field-operations for the season. Twelve signals were erected and observed on, and thirty-two horizontal angles were measured by lines of from 18 to 35 miles in length. The heights of four stations were determined by vertical angles. The records, since deposited in the office, include angular measurements made from the stations which were occupied, on prominent church-spires, for determining, in relative positions, Troy, Ballston, Saratoga, Schuylerville, and other towns and villages that could be seen from the mountain-stations.

At intervals when the observing instruments were in transit, Mr. Cutts conferred personally at Cube Mountain in reference to the interests of the work in progress at that station under the charge of Professor Quimby, and also with Assistant Perkins, whose work at Ragged Mountain, on the coast of Maine, has been a subject of mention under the head of Section I in this report.

Arrangements are now in hand for completing the observations requisite at Mount Rafinesque.

Latitude and azimuth at Rouse's Point, N. Y.—In the course of the summer and autumn of 1874, astronomical observations were made by Assistant G. W. Dean, at several stations between the United States boundary-line near Lake Champlain and Catskill Mountain near the Hudson River. His party took the field early in August, and first occupied "Astronomical Hill," one of the stations used in the triangulation of Lake Champlain. The station is not far from one of the points occupied in 1845 by Major Graham, U. S. A., for establishing the boundary-line between the United States and Canada. Finding in place several of the granite blocks on which the astronomical instruments were adjusted in 1845, Assistant Dean made careful measurements, and noted the distances between them and his own station on Astronomical Hill. There the latitude was determined from 176 observations on 23 sets of stars with zenith-telescope No. 4. Nine nights favorable for observing were occupied in this work. The arc-value of the micrometer was found from 147 observations during three nights on Polaris near eastern elongation.

Azimuth at Astronomical Hill was ascertained from the record of 86 observations with the 46-inch Transit No. 4 on δ Ursæ Minoris near its upper culmination, and an equal number on 51 Cephei near lower culmination, with lamps east and west. These observations in the course of six nights were referred by 116 pointings upon a meridian-mark, which had been set up about half a mile north of the astronomical station. A meridian-line was traced on the Government reservation, and Mr. Dean carefully marked the ends by drill-holes in the tops of granite posts, which were sunk four feet into the ground. The station occupied for latitude is about midway in the meridian-line, and the position occupied by the zenith-telescope was marked by a granite post similar to those placed at the ends of the line.

For local time at the station on Rouse's Point, Mr. Dean recorded 59 observations on 12 standard stars with the transit-instrument.

The angle between the meridian-line and Windmill Point light-house was carefully measured with the 10-inch Gambey theodolite No. 63 by means of 432 readings of the horizontal angle.

Capt. David White, civil engineer, who was at Fort Montgomery while astronomical work was in progress, extended all the facilities at his command to further the operations at Rouse's Point.

Cheever Station, about two miles north of Port Henry, N. Y., was occupied by Assistant Dean, in the middle of September, with the instruments which had been used for latitude and azimuth determinations in August. For latitude at *Cheever*, 168 observations were made on 21 sets of stars during five nights, and 94 observations were recorded for arc-value of the micrometer. Azimuth was determined as usual by an aggregate of 172 observations on six nights; 120 pointings on a meridian-mark and 372 measurements of the horizontal angle were made for referring the azimuth-determinations to Station Whitford on a line of the triangulation. For local time, observations were repeated on seven nights. The work at Cheever Station was closed on the 6th of October. As soon as practicable, Mount Merino, near Hudson, N. Y., was occupied by Assistant Dean for similar determinations. There the latitude was found from 146 observations on 18 pairs of stars on six nights, and 135 observations were recorded for the value of micrometer-divisions.

For azimuth, 77 observations were made on λ Ursæ Minoris near upper culmination, and 60 on Polaris; and 164 measurements were made for connecting the azimuth-determinations with the mark. A signal-pole was set up on Catskill Mountain; but, though the distance from Mount Merino was less than 12 miles, the signal was commonly obscured in the latter part of October and early in November by the haze then prevalent along the Hudson Valley. Mr. Dean, however, ultimately referred the azimuth-mark to the triangulation by 696 measurements of the horizontal angles between the mark and the signal-poles at Catskill Station and Mount Merino.

Mr. A. G. Pendleton served as aid in the astronomical party, and subsequently was engaged in Section VII. Assistant Dean closed the work at Mount Merino on the 14th of November. The original records of his observations have been duplicated and deposited in the office, and the computation of results is now well advanced.

The proprietor of Mount Merino, Capt. William J. Wiswall, afforded many facilities for the service of the party while the work was in progress at that station.

Shore-line survey of Lake Champlain.—This shore-line survey was completed before the approach of winter, in 1874, by two plane-table parties, the work of which was joined at a point not far below Ticonderoga.

Assistant C. T. Iardella took the field early in May. After mapping in outline the islands known as "Four Brothers," he joined with previous work on the east side of the lake at Paxton's Point and on the west side at Ligonier Point, and from thence extended the survey southward. His work is on five sheets, which show the several harbors of the lake between Burlington and Crown Point. Amongst these are McNeil's Bay, Arnold's Bay, Gray's Basin and Rock Harbor, Northwest Bay, and Whalon's Bay. The roads in the immediate vicinity of the lake appear as details, and also the villages that adjoin the water-line. After completing the general survey to the point designated at the outset of the season, Mr. Iardella made a detailed topographical survey of the vicinity of Crown Point on a scale sufficient to admit of marking in position the outlines of all the fortifications and defensive lines that could be identified. Remembering that while interest in such remains is deepening, the objects themselves are wasting away and must soon disappear, it will be deemed a duty to include in topographical operations the mapping of localities that have been famous or noteworthy in our early history, when the places chance to be within the projected limits of work, as in the case here mentioned.

Subassistant H. W. Bache was attached to the party of Assistant Iardella.

Subassistant Andrew Braid, with a separate topographical party, took the field on the 1st of June. Beginning at a point agreed upon in conference, below Crown Point, the shore-line survey was extended from thence southward to include Whitehall. In the course of the operations, numerous points were determined for use in the hydrography, and tracings of shore-line were furnished as the work advanced. At Ticonderoga, Mr. Braid made a special survey, on a large scale,

of the old fort and its vicinity. Traces of all the defensive lines and redoubts were carefully sought for and delineated. Contours of such as could be identified were traced to show the ground-elevation as it now exists. The walls of the old fort are crumbling rapidly, and, as the fragments are passing away in the hands of tourists, the spot must soon be left without any trace either of the ruin or of its foundation. Mr. Braid found that the old French lines of 1758 were tolerably well preserved in places; but, at the eastern limit of the works, the lines have been nearly obliterated by the plow. Subassistant Braid was aided in the field by Mr. C. H. Sinclair. The work of the season done by the two plane-table parties is shown in the following statistics:

Shore-line surveyed, miles	235
Roads, miles	99
Marsh-outline, miles	47
Area of topography, square miles	20

Assistant Iardella during the winter conducted a plane-table party in Section IV. Subassistant Braid was at the same time in service which will be mentioned under Section VIII.

Hydrography of Lake Champlain.—Within the plane-table limits of the present year, the hydrography of the lake has been completed by a party under the charge of Mr. Charles Junken, working with the steamer Fathomer. Soundings were begun in Shelburne Bay in the middle of June, and were finished on the 6th of July, 1874. After completing work in Willsboro' Bay, Mr. Junken proceeded to Crown Point, and there resumed the general hydrographic survey, all the waters north of that point having been previously sounded. Weather being favorable, the work in going southward reached Ticonderoga by the 8th of August. During several weeks succeeding that date, the charge of the hydrographic party devolved on Mr. E. H. Wyvill, in consequence of the illness of Mr. Junken. Mr. G. A. Morrison served as aid. Work was steadily pushed until the 10th of October, when the sounding party had passed Whitehall and completed the hydrography of the lake, including at its southern limit the expansion known as South Bay, below Whitehall. The following are statistics:

Miles run in sounding	507
Angles	10,432
Number of soundings	43,481

As evidenced by the number of recorded angles, the hydrography below Crown Point, in places likely to be under consideration for future improvement, was prosecuted with reference to such contingency. After completing his manuscript sheets of the lake hydrography, Mr. Junken resumed duty as draughtsman in the office. At the end of June of the present year, he was detailed to examine and report on shore-line changes and sea-encroachment on the coast of South Carolina. The results there found will be mentioned in Section V of this report.

Survey of Hackensack River, N. J.—As far up as Hackensack, and in the lower part of English Creek, soundings were made in the river in 1873, and the shores had been previously traced. In the middle of October, 1874, Assistant Gerdes commenced a plane-table survey of the ground along both sides of the Hackensack, and extended the detailed topography eastward to the New Jersey Northern Railroad, which passes along the western edge of the Palisade Ridge. Most of the area surveyed is marsh, but it includes many patches of well-cultivated land, and is crossed by plank-roads, turnpikes, and railroads. This work was completed early in November. The statistics are:

Shore-line surveyed, miles	16
Roads, miles	27½
Area of topography, square miles	8

Subassistant Dillaway was engaged in this work under the direction of Assistant Gerdes, and Mr. C. A. Ives served in the party as aid during part of the season. After refitting at Baltimore, the schooner Dana was employed during the winter in Section IV.

Station-marks.—The prospective requirements of field-work in the vicinity of New York Harbor making it desirable to refer to Beacon Hill and Weasel, two stations occupied in the early

survey of that region, Assistant Edward Goodfellow was directed to search for the marks which had been set in the ground, and thus to identify them as points used in the general triangulation of the coast. With the requisite office-data and descriptions of the stations, Mr. Goodfellow took the field in August, 1874, and, from a preliminary station on Beacon Hill, observed upon five known points of the secondary triangulation. From one of these, at Elm Tree Beacon, angular measurements were also made, the purpose being to identify the point which had been occupied by the theodolite in a former year on Beacon Hill. Having ascertained within close limits the locality in which the early signal must have stood, Mr. Goodfellow next proceeded to Weasel, to search for the ground-marks. These he readily found by clearing the rock of earth and moss which had gathered on it in the course of years since the station was first occupied. After adjusting a signal-pole over the point to be observed on from Beacon Hill, Mr. Goodfellow visited that station, and, applying results gathered from angular measurements at the others, found, after due search, the stone cone which had been buried there by Superintendent Hassler. This work was completed on the 18th of September, when descriptions applicable to the present condition of the stations were filed at the office, with sketches to facilitate identification of the points in future. Mr. C. A. Ives aided in the field-operations.

In December, Assistant Goodfellow was assigned to duty under the direction of the assistant in charge of the office in Washington.

Physical survey of New York Harbor.—As far as practical purposes have demanded, this work has been pursued systematically. The harbor has undergone some changes since the early surveys were made, and these alterations, with their causes, make the subjects of operations and studies at this time. Incidentally, however, an investigation of the relations of the channels to the streams that traverse them is continued by Assistant Henry Mitchell, and is expected to show at what points the old pier-lines are at fault, and the proper location for new ones, not only where faulty ones exist, but also in localities not yet occupied.

The deepening of the Hudson below Castle Point, referred to in a previous report, naturally suggested an inquiry into the causes of the excavation and the disposal of the material removed. A glance at the earlier harbor-chart shows that this part of the river was originally of adequate depth for all the possible wants of navigation, and that the deepening is not only no improvement, but implies injury elsewhere, since a very large volume of material must have been deposited in other parts of the harbor. It seems probable that the general occupation in later years of the New Jersey shore, and the erection of numerous wharves, etc., on that side of the river, have restricted the former flow, and that increased scour has been thus induced.

The utilization of hitherto worthless flats, even if some such consequences as those referred to must follow, is not necessarily inexpedient, but in the case under question a proper study of the natural conditions in advance of the erection of structures might have secured the community against undue sacrifices. The commission of United States officers, requested by the State authorities of New York to rectify the pier-lines of Brooklyn, owes its origin primarily to complaints against the extension of wharves beyond the previously adopted harbor-lines. That board, having no power to remove the extensions, which seem to have been made without any previous study or consultation in regard to their probable effect on the channels, was constrained to locate a new pier-line, more advanced than the old one, in order to mitigate the injurious effect of the obstructions. Researches in the physical survey have had direct bearing on the conclusions reached, and at times the observers in the party of Mr. Mitchell have rendered immediate service to meet the requests of the board.

Immediately after his return from Central America, Professor Mitchell arranged a project for further operations in New York Harbor. The schooner Research was equipped and ready for work on the 8th of July. Assistant H. L. Marindin took charge of the party, and Mr. J. B. Weir served as aid.

In East River, six transverse curves of velocity were determined, both for maximum ebb and maximum flood. These were compared, each with the profile of the section sounded out at the same time, and connected by tracing free floats, the courses of which were determined by many *three-point* positions.

Subsequently, work in Hudson River and along the western part of the main channel of the harbor was taken up; four transverse curves were determined, and these were connected and extended by twenty-nine trips with free floats. Peculiar difficulties are offered in the Hudson. Many stations are needful to give the transverse curves of velocity, and, if not observed on simultaneously, corrections cannot well be applied for variations in the river-outflow.

Part of the design in view is to draw isodynamic lines through the harbor-chart, and exhibit their relation to the submerged contours, especially where the bottom is yielding, but also where the flow is subordinated to the form of the channel. It is obvious that such a chart, if satisfactorily made, would show directly where artificial improvement of the channel will accord with, and where it would violate, natural rules; which of the shoals were antecedent to the existence of the present currents, and which of the shoals resulted from these movements—the first belonging to the class of obstructions that can be permanently removed, the last to the class of shoals that will at some future time re-appear.

In the course of the work in New York Harbor, it has become evident that observations in summer and autumn, which have been our working-seasons there, must be supplemented by observations made in the spring, in order to find co efficients for the flood periods.

Earnest call having been made for similar observations in Providence Harbor, notice of which has been taken under the head of Section I, the work near New York was closed on the 1st of September, 1874. Subsequently, the party was employed in special observations at the Mississipp delta.

Hydrography of New York Bay.—During the month of July, 1874, the party of Assistant F. F. Nes, in the steamer Arago, was employed in sounding the parts of the lower bay which had not been reached in the operations of the preceding season. While that work was in progress, my attention was asked to determine whether the harbor-dredgings for the final deposit of which certain localities had been indicated were moving so as to lessen the depth in the adjacent channel, an inquiry based apparently on the supposition that the barges of many contractors were all towed in accordance with the "permit" to the designated sites, and discharged within the limit of depth specified when the dumping-grounds were selected. Assistant Marindin being then in the vicinity, and knowing the requirements which were carefully inserted in each permit, soon observed that barges were discharged elsewhere. While pointing out to Assistant Nes the signals used in the survey of 1873, which resulted in selecting the place of deposit, Mr. Marindin saw some barges depositing material in the channel at a position less than three-quarters of a mile from the Fort Tompkins light-house. Their movements in reaching the place, moreover, made it very likely that the "permit" to dump material only in depths greater than six and less than twelve feet had been generally disregarded. Inquiries by some of the members of the Board of Commissioners of Pilots led to the same conclusion. Under the advice of Professor Mitchell, a resurvey was made of West Bank channel and dumping-ground by the party in the Arago. Mr. Nes completed that work on the 24th of August, and then sent to the office the records of the hydrography and specimens of the bottom. Soundings were resumed in the vicinity of Southwest Spit, and there the operations of the party were continued until the 10th of October, when the Arago returned to port, to be refitted for hydrographic service which will be mentioned hereafter. Master H. O. Handy, U. S. N., joined the vessel on the 13th of August, and assisted in the work in New York Bay. The following is a synopsis of the statistics:

Miles run in sounding	390
Angles measured	4,934
Number of soundings	19,607

Assistant Nes was aided in this section by Mr. W. B. French. Lieutenant Handy took charge of the steamer Arago at the end of October, and subsequently conducted the operations of the party in that vessel, as will be stated under Section IV.

Tidal observations.—The self-registering tide-gauge, though of the old form, in charge of Mr. R. T. Bassett, was kept in operation throughout the severe weather of last winter at Governor's Island, New York Harbor, by the free use of warm water when circumstances so required. Only a few interruptions appear in the register, and correspond to periods when, because of the floating

ice, the observer found it impossible to reach the tide-gauge. As heretofore, Mr. Bassett records the tides also with a box-gauge at Hamilton avenue in Brooklyn.

Places have been selected at Sandy Hook and Throg's Neck for the establishment of self-registering tide-gauges, and it is hoped that series of observations may be commenced at an early day.

In the following extract, Lieutenant Hitchcock mentions an act of noble daring by a member of his hydrographic party, of the steamer Endeavor, at Jersey City, on the 25th of June of the present year, when arrangements were in progress for transferring the party from that vessel to the steamer Gedney, and which is here cited as specially commendable:

"While on shore, Henry Rynders, seaman of this vessel, noticed a crowd, and on inquiry found that a boy in playing ball had accidentally fallen into a sewer, and that he had been swept under the street and beyond the reach of a rake, the only means tried in the course of nearly twenty minutes for his recovery. Rynders procured a rope, lowered himself into the sewer, found the boy, almost lifeless, about 15 feet from the opening, and brought him up."

The rescue of the boy by a humane impulse stronger than any sense of personal risk was promptly noticed by the American Benevolent Life Saving Society of New York. The silver medal of the society, suitably inscribed, and a substantial token in money, awarded by the society to Henry Rynders, seaman, have been transmitted by its president, Ellwood Walter, esq., with a communication expressing the exalted motives that prompt such awards.

Survey of Great South Bay, Long Island, N. Y.—This work was resumed by Assistant Charles Hosmer on the 23d of June, 1874, at Islip. In the course of the season, the detailed topography was extended eastward along the upper shore of Great South Bay as far as Howell's Point. Conformable to the same limits east and west, the strip of land bounding the south side of the bay was mapped on the plane-table sheet. Soundings were taken up at Nicholl's Point, where hydrographic work had closed in the preceding season, and were extended eastward to Howell's Point. On the north side of the bay, the survey includes Patchogue and all artificial improvements now existing between the water-line and the railroad. Under direction of Mr. Hosmer, the soundings were prosecuted by Subassistant L. B. Wright in the schooner G. M. Bache. Mr. J. De Wolf aided in the plane-table work. The statistics are:

Shore line surveyed, miles	46½
Roads, miles	101
Area of topography, square miles	23
Miles run in sounding	219
Angles measured	1,169
Number of soundings	20,241

The party was disbanded on the 26th of September. Its subsequent operations will be mentioned under the head of Section VI.

Reconnaissance.—At the request of the governor of New Jersey, and in behalf of the geological survey now in progress in that State under the direction of Prof. G. H. Cook, arrangements have been made for the determination of points to serve in correcting the State map. The examination of the ground for stations has been committed to Prof. E. A. Bowser, who will take the field in the course of the summer in the vicinity of New Brunswick.

Topography of Barnegat Bay, N. J.—For resuming field-work on the coast of New Jersey, the party of Assistant C. M. Bache was organized on the 16th of July, 1874, and a plane-table sheet was projected for details of survey along the western side of Barnegat Bay, between the town of Barnegat and the north shore of Tom's River. Field-work was continued until the 6th of November. After tracing the shore-line, the surface-features adjacent were mapped inland as far as the road which passes from Tom's River to Barnegat. The survey was closed for the season on the south side of the river, where it will be resumed in the summer of 1875 by the same party. Statistics of work for the present season are:

Shore-line surveyed, miles	159
Roads, miles	106
Area of topography, square miles	38

Subassistant H. M. De Wees was attached to this party, and Mr. J. J. Evans aided in the field-work.

As means for transportation, Assistant Bache used a barge, which has proved to be well adapted for conducting plane-table operations in the vicinity of shallow waters. It is expected that in the coming season the detailed topographical survey of the coast of New Jersey will be made continuous from Sandy Hook to a point below Absecom Inlet.

Hydrography of Barnegat Bay, N. J.—Early in July, 1874, the party of Subassistant W. I. Vinal was transferred to the schooner Bibb. The vessel left Norfolk on the 11th of that month; but, owing to adverse winds, five days were spent in reaching the working-ground on the coast of New Jersey. Notice will be taken presently of the survey, which was immediately taken up, but in geographical order mention must be made of the work which was commenced on the 20th of August in Barnegat Bay. During an entire month from the outset, soundings were prosecuted under great disadvantage, the air being clouded by smoke from extensive tracts of burning forest. By the 8th of October, however, the entire bay, which is about 12 miles long and from 2 to 5 miles wide, was completely sounded out. Ten stations on shore were occupied for determining the positions of signals. The ordinary hydrographic statistics are:

Miles run in sounding	330
Angles measured	2,264
Number of soundings	56,234

In the progress of this survey, the positions of six life-saving stations and five buoys were determined.

Subassistant Vinal took up the hydrography of the entrance to Little Egg Harbor on the 20th of July. The lines of soundings required, being outside, could be run only at intervals, during which the irregular "dry northeaster" was not blowing on shore. No opportunity for advancing the work was lost, and by the 13th of August the hydrography of the entrance and approaches to Little Egg Harbor was completed. While the work was in progress, the officers engaged in light-house service renewed the buoys and moved several of them in position. All the positions, thirteen in number, were carefully determined by Mr. Vinal, and are marked on his hydrographic-sheet. In this vicinity, he determined also the positions of three life-saving stations. The general statistics are:

Miles run in sounding	101
Angles measured	913
Number of soundings	9,587

Mr. E. B. Pleasants served as aid in the hydrographic party, and accompanied Mr. Vinal for similar duty in Section IX, under which mention will be made of the occupation of the party during the winter and spring.

In going northward in the steamer Bache, for service which has been stated under the head of Section I, Acting Master Platt passed, on the 19th of July, 1874, off Barnegat, a large spar, which seemed to project from a sunken wreck. Near the spar, the depth of water was thirteen fathoms, the light-house bearing north-northwest, and distant about nine miles. Prompt notice was given through the press in regard to this obstacle, which, for any period that the wreck might hold the spar in place, would be highly dangerous to navigation.

Triangulation, topography, and hydrography in Delaware River.—This work was prosecuted at the request of the Light-House Board, to meet the requirements of that service for the proper location of range beacons as aids to navigation in the Delaware, near Liston's Tree, and also for entering the mouth of the Schuylkill. Of necessity, the hydrography of the channels was revised in both places, the channel into the Schuylkill having been recently altered by dredging, while that near Liston's Tree was represented only by the soundings made many years ago. In order to provide the points requisite on land, Assistant J. A. Sullivan took the field on the 26th of April, and, with the aid of Mr. C. L. Gardner, soon identified the station-mark which had been placed in the ground at Port Penn as one of the points in the triangulation of Delaware Bay. The line to Reedy Island light-house serving as a base, suitable angular measurements were interpolated, and

twenty-seven additional points were furnished for the use of the hydrographic party. These were determined by 1,440 observations with the theodolite.

After providing the requisite projections, Assistant F. F. Nes proceeded to Delaware City on the 19th of April, and set up a tide-gauge there, and another at New Castle. At Collins' Beach, tidal observation were also recorded. Until the 4th of May, the party was employed in erecting signals, under the disadvantage of continuous bad weather. The light-house steamer Violet, assigned as means for transportation, was soon withdrawn under an exigency of the service, but was replaced a week afterward by the cutter Rose. During that interval, Assistant Nes prosecuted soundings with a small boat. Progress in the work was very satisfactory after the middle of May, and, in the course of the following week, the hydrography of the channel was completed. Positions for range-lights were then selected, tripods were erected over the points, and lines of soundings were run between the tripods on the selected ranges. The least depth found on either side of the range was twenty feet.

In this service, Mr. Nes erected twenty-two tripod-signals, and carefully determined the positions of seven buoys. The general statistics of his work are as follows:

Miles run in sounding	248
Angles measured	1,579
Casts of the lead	8,772

The report of Assistant Nes includes descriptions of the signals used for the hydrography, and of the ground selected as sites for the range-beacons. Messrs. R. B. Palfrey and C. H. Sinclair served as aids in the party of Assistant Nes.

The party assigned for revising the hydrography at the mouth of Schuylkill River was placed in charge of Mr. Charles Junken, who conferred immediately with General Raynolds, the light-house engineer at Philadelphia, and commenced work on the 30th of April. Mr. Junken used the plane-table for tracing the shore-lines of the lower part of the Schuylkill and of the adjacent part of League Island. By the same means, he determined in position a number of poles placed at low-water mark, each being the end of a subsequent line of soundings. As the work advanced, the soundings reduced to mean low water were plotted on the chart. The result shows that a depth of 19½ feet can be carried into the mouth of the Schuylkill and up to Penrose Ferry Bridge. Positions for the range-lights were then marked by tripods on the ground.

On the 11th of May, General Raynolds went on board of the light-house cutter Rose, and passed into the Schuylkill by the ranges as marked, finding a depth of 20 feet on the bar. Soundings above the bar, however, developed the existence of some obstruction, which subsequently proved to be a sunken coal-barge, and near it a pile of stone, probably the discharged ballast of a vessel. These obstructions were marked on the chart, copies of which have been furnished for the uses of the Light-House Board. The general statistics are:

Miles run in sounding	11
Number of soundings	1,987

Geodetic survey in Pennsylvania.—At the instance of the State geologist, Prof. J. P. Lesley, request was made early in the summer, by the governor of Pennsylvania, for the co-operation authorized by law in regard to extending the triangulation of the coast so as to determine points for correcting the State map. Prof. L. M. Haupt, of the University of Pennsylvania, who has been accepted as field-observer, conferred personally at the Coast Survey Office in June, and is now conducting a reconnaissance in the Lehigh mining region, where it is desired by the State geologist that the accurate determination of points should be commenced.

SECTION III.

ATLANTIC COAST AND BAYS OF MARYLAND AND VIRGINIA, INCLUDING SEAPORTS AND RIVERS.

(SKETCH No. 6.)

Special survey of Craney Island, Va.—While Assistant J. W. Donn was yet engaged in arrangements for resuming field-work on the James River, request was made by the chief of the Ordnance Bureau of the Navy Department, Capt. W. N. Jeffers, for a minute topographical survey of the ground of Craney Island, above the low-water shore-line. This and similar calls of course have in view such delineations of surface as will meet all possible requirements in engineering operations. At Craney Island, the earthworks thrown up in 1861 were found by Mr. Donn, in December, 1874, as broken irregular mounds, hillocks, and ridges. He developed the entire surface of the island by contours, to show each successive foot in vertical height of the ground above the low-water line, and mapped the features on a scale suitable for engineering purposes. The Ordnance Bureau having defrayed the expenses incurred in this special survey, a copy of the resulting map was transmitted to Captain Jeffers for the archives of the Navy Department. Field-work at Craney Island was concluded by Mr. Donn in the third week of December. His party then took up service which will be mentioned under the next head.

Supplementary hydrography.—For the completion of the chart of Elizabeth River, the shallow passage between Craney Island and the mainland was sounded out in August, 1874, and several lines were added, giving additional soundings in Elizabeth River near the western end of the island. Mr. James B. Baylor, who was detailed for this service, promptly turned in the resulting sheet, on which is the following synopsis of statistics:

Miles run in sounding	7
Angles measured	100
Number of soundings	1,126

Mr. Baylor had been previously engaged in Sections VI and VII.

Tidal observations.—A self-registering gauge of the new form, with large interchangeable cylinders, reading-box, and clock with a balance-wheel, is now in operation at Fortress Monroe, in charge of the observer, Mr. W. J. Bodell. The record of tides at this station has been much improved by substituting the time-keeper now in use for the pendulum-clock, which, in rough weather, was liable to stop, and thus occasion breaks in the tidal register.

Survey of the Chickahominy River, Va.—In the preceding season, this work had been extended from the mouth of the river upward to Ship Yard. Assistant Donn there resumed the survey in the latter part of December, 1874, with his party, in the schooner Scoresby; roughness of the weather making it inexpedient to undertake operations in the broad waters of James River at that period.

The triangulation of the Chickahominy was continued from the point gained in the general work of the previous season, and was carried to the head of navigation. Subsequently, the topography was mapped to represent a margin about one mile wide on either bank, and as far up the stream as the old English cut or canal at Forge Bridge. The river was sounded within the same limits. Much inclement weather and the unusual thickness of ice in the river made this service difficult, but the work was finally accomplished in March within the limit of time assigned for its completion. The Scoresby was then immediately passed into the James River for further service. In the Chickahominy, the tides were recorded at Mount Airy and Window Shades for short periods; and, for an entire month, all the high and low waters were recorded by means of a tide-gauge at Graves' Landing.

Survey of James River, Va.—When the work described under the preceding head was closed, the severity of the season had remitted. Good weather followed in April and May, and, under favorable circumstances, Assistant Donn resumed the detailed survey of the James River at Sloop Point. As the work advanced toward City Point, the details of topography were mapped to represent a margin of the usual width on each side of the river; and, of the several branches of the river within the limits of the survey, the shore-line and adjacent topography were included. All

the creeks not too shallow at the entrance to admit the boats of the Scoresby were sounded generally by lines along the axes of their channels. The work was extended up the James River as far as means available for the season would allow, and was closed for the fiscal year on a line from the middle of Eppes Island to the terminus of the railroad on City Point.

The tides were observed by means of temporary gauges at Brandon Point, Dunmore Wharf, and Wilcox's Wharf. At Jordan's Point light-house, each recurrence of high and low water was recorded during twenty-six consecutive days. The datum-planes of the gauges from Brandon to Jordan's Point were connected by a line of levels run at intervals during April and May.

Assistant Donn was aided in field-work in this section by Messrs. F. C. Donn, F. H. Parsons, and C. A. Ives, and, after February, also by Mr. D. C. Hanson. The statistics of work are for the surveys on the James River and the Chickahominy:

Stations occupied in triangulation	44
Angles measured with theodolite	152
Shore-line surveyed, miles	199
Streams, miles	94
Roads, miles	144
Area of topography, square miles	91
Miles run in sounding	426
Angles (sextant)	2,722
Number of soundings	23,051

Under Section I, in which the party is now engaged, notice has been taken of the service performed under the direction of Assistant Donn in the summer of 1874.

Magnetic observations.—At the standard station, on Capitol Hill, Washington, D. C., observations for the magnetic declination, dip, and intensity were made, in June of the present year, by Assistant Charles A. Schott. This is the eighth year in the series of determinations by the same observer. The discussion by Mr. Schott, and conclusions reached in regard to the magnetic elements at the station on Capitol Hill, were given in my last annual report.

Triangulation in Virginia (Sketch No. 8).—For extending southward the primary triangulation which crosses the Potomac in the vicinity of Washington City, Assistant A. T. Mosman took the field on the 10th of June, 1874, and occupied Mount Marshall in Rappahannock County, Va. The month of June was spent in visiting and adjusting signals at the stations of the main triangulation as they were left in 1871. Observations for horizontal angles were begun with a new 14-inch theodolite at Mount Marshall early in July, but progress in the work was much hindered by haze, so that angular measurements from that station on eight primary, two secondary, and twelve tertiary signals were not completed until the 8th of September. Vertical angles were measured on eight of the outlying stations. The summit of Mount Marshall is 3,850 feet above the sea, and is so difficult of access that Mr. Mosman of necessity pitched the camp of his party about six hundred feet below the observing-station. The close of operations there was followed by several weeks of rainy or thick weather, in the course of which the party and instruments were transferred to Fork Mountain in Madison County. Between the 12th and 21st of October, a few observations were secured and recorded at that station; but generally then, and continuously afterward until the 20th of November, the atmosphere was so smoky that mountains only ten miles off could not be seen in outline. The party, however, though under much hardship, remained, and recorded angular measurements at all favorable moments, until the 26th of December. For some weeks, Fork Mountain and the neighboring summits had been covered with snow and ice, and communication between the party at the station and the lower country was cut off for days at a time. The field-records show that angular measurements were made from Fork Mountain on ten primary, three secondary, and twenty-one tertiary signals, and that differences in height were measured by the micrometer on twenty-one outlying stations. Four heliotropes were used for determining the direction of the longest lines in the triangulation. The party was disbanded on the 31st of December. During the next three months, Assistant Mosman, and his aid, Mr. D. S. Wolcott, were employed in computing results from the records of field-work. April and May

were occupied in reconnaissance for stations, to connect properly with Humpback Mountain, for the measurement of horizontal angles. Mr. C. L. Gardner was temporarily attached in December, and was again assigned to duty in the party in June last. The general statistics of the work are:

Signals erected	6
Directions determined	20
Number of observations	1,498

At the end of June, observations were closed at Humpback Mountain. The party was then transferred to Spear Mountain, at which the work prosecuted will be made the subject of notice in my next report. At Humpback, the differences in height between that and four other stations were determined by means of the vertical circle. Owing to the difficulty of access, the observer's tent was of necessity four miles distant from the station, a condition adding much to the labors of the party in this region.

Reconnaissance.—For the extension of a chain of triangles westward from points in the series which passes southward along the Blue Ridge in Virginia, Assistant S. C. McCorkle took up the work of reconnaissance in the middle of July, 1874. Humpback Mountain and the primary station at Fork Mountain being approved as starting-points, Mr. McCorkle visited Elliott's Knob; in connection with it, afterward selected a station in Rockingham County at State Spring; and from thence passing into Pendleton County, he examined the country from the summit of Panther Knob. Several mountains in Highland County were visited, and Paddy's Knob was selected as a station. This is on the Alleghany Range, and near the corner of Bath and Highland Counties. Subsequently, positions were examined near Covington, and others in the southwest part of Pocahontas County and on the borders of Summers and Greenbrier Counties. In the region of the Kanawha, points were examined on Sewall Mountain and Gauley Mountain. In Fayette County, Payne's Mountain was selected, and, visible from it, a point in Nicholas County, west of Summersville. Toward the Ohio River, the elevations are less, some being twelve hundred and others not more than eight hundred feet above the general level of the region.

The results of this reconnaissance make it probable that a good scheme of triangulation is practicable between the Shenandoah range of mountains and the Ohio River. Assistant McCorkle's report was accompanied by a sketch showing the approximate positions of stations which had been found intervisible, and notes in regard to local facilities and means of transit from place to place. His subsequent work in reconnaissance will be mentioned under the head of Section VII.

SECTION IV.

ATLANTIC COAST AND SOUNDS OF NORTH CAROLINA, INCLUDING SEAPORTS AND RIVERS.—(SKETCH No. 7.)

Triangulation of Pamplico Sound, N. C.—As mentioned in my report of last year, this work has been prosecuted continuously by the party under the charge of Assistant G. A. Fairfield, and is now completed. Early in the fiscal year, the station at Stumpy Point was occupied, but observations there were long delayed in consequence of the volume of smoke brought from the burning pines of the Dismal Swamp. Mr. Fairfield completed the angular measurements at that station on the 25th of November, 1874, and then transferred his party in the steamer Hitchcock to Gull Island, where observations were continued until the 12th of February of the present year, through the coldest and most stormy season yet experienced in the sound. In that interval, a boat's crew, sent to Newbern for the mail-matter which had accumulated, nearly perished; but, though coated with ice an inch thick, the men were safely landed at the mouth of Neuse River by the energy of Mr. T. G. Dixon, sailing-master, who was in charge of the cutter.

While observations were in progress at Gull Island, Mr. B. A. Colonna, aid, was sent to Cape Hatteras, and there determined the position of the old light-house, and chained the distance between it and the new structure. The positions of both, relative to the beacon-light, were determined by angular measurements.

On the 20th of February, a station on the eastern side of Pamplico Sound was prepared at Pea Island. Assistant Fairfield visited the light-house at Roanoke Marshes, but found the structure

and the ground anywhere near it too unstable as a place for the theodolite, and of necessity established a station on the west margin of Roanoke Island, at a point nearly three miles northeast of the light-house. Angular measurements at the station (named Sand Island) were completed on the 25th of March. Subassistant Colonna and Mr. W. B. Fairfield, aid, were then detailed to make the observations at Pea Island, and completed work there on the 19th of April. The only anchorage for the steamer in that vicinity being much exposed, the party lived in camp while at Pea Island. Next in order, the north and south ends of the base line at Bodie's Island were occupied with the theodolite by Mr. Colonna, and horizontal angles were measured upon the three signals in view, connecting that base with the triangulation of Pamplico Sound. One of the granite monuments set to mark the south end of the line had been overturned and broken within the past ten years, but was again replaced by Mr. Colonna, and securely marked.

After completing the triangulation, Mr. Fairfield determined the positions of two of the new light-houses erected within a few years as aids to navigation in the waters north of his locality of work. A signal was erected, and three stations were occupied for ascertaining the position of Croatan light-house. The structure now in course of erection at Currituck Beach was also determined in position. Finding by examination that known points were not available for determining the lights at Wade's Point, North River, and Pasquotank River without additional field-work, the party in the steamer Hitchcock was recalled from this section in the middle of June, and proceeded to Baltimore, where the vessel will be refitted for other duty. The statistics of the concluding field-work in Pamplico Sound are:

Signals erected	4
Primary stations occupied	6
Secondary stations occupied	8
Angles measured	73
Points determined	22
Number of observations	5,886

The field-records, containing descriptions of the stations and angles observed, have been duplicated and compared, and, together with the computations by the observers, have been deposited in the office.

At the end of the fiscal year, Subassistant Colonna was detailed to conduct a party in Section II.

Topography of Pamplico Sound, N. C.—In the field operations of the fiscal year 1874–'75, the shore-line survey of Pamplico Sound was completed by a party under the direction of Assistant C. T. Iardella, who resumed work in this section with the schooner Dana on the 7th of December, 1874. Commencing at Long Shoal signal, and as data for the immediate uses of the hydrographic party, in the steamer Arago, the shore-line was carefully traced as far as Hog Island. In the same direction, the survey was then prosecuted to a junction at Juniper Bay, with the field-work done in a previous year. Resuming again at Long Shoal signal, Mr. Iardella extended the survey northward, and joined on the 14th of May with a plane-table sheet of the year 1864, showing details of the shore in the vicinity of the light-house at Roanoke Marshes. The three plane-table sheets returned to the office by Assistant Iardella show several small bays on the west side of Pamplico Sound. In reference to their importance as harbors for local trading-vessels, the following remarks are made in the field-report:

"West Bluff Bay, two miles wide, with good anchorage in ten feet, is a safe harbor for small vessels in all except southwest winds. East Bluff Bay is also a safe harbor, excepting in heavy southeast weather."

"Yesocking Bay, the entrance of which is sheltered by Gull Shoal, receives vessels drawing eight feet, that load with corn and cattle brought down in scows through the canals that traverse the adjacent country."

"Long Shoal River is two miles wide at its entrance, and four miles long. Vessels can anchor in twelve feet and be safe in all winds; but as yet the shores are not occupied, the nearest habitations being fifteen miles from the river."

Subassistant H. W. Bache was in service in this plane-table party. The statistics of work are:

Shore-line surveyed, miles	171
Roads, miles	32
Water-courses, miles	17

Finding that the islands near Roanoke Marshes light-house had been washed and lessened by the action of the water in the course of the last ten years, Mr. Iardella resurveyed their shore-lines, and mapped them in relation with the shore-line of his upper plane-table sheet. The abrasion observed principally affects the islands on the side which is exposed to the open water of the sound.

Hydrography of Pamplico Sound, N. C.—The progress made in the course of the fiscal year by Lieut. H. O. Handy, U. S. N., has advanced toward the completion of the hydrography of Pamplico Sound. His party, in the steamer Arago, left Baltimore early in December, 1874, and by the middle of that month reached Washington, N. C. Signals were set up without delay on the shores of Yesocking Bay, the shores of which had been traced by the plane-table party, as stated under the last head. Lieutenant Handy established a tidal station at Pamplico light-house, and there had observations recorded while the soundings were in progress. The work closely occupied the party in the Arago from the 14th of January until the 27th of May, when operations in this section were closed for the season. The steamer Arago then sailed for New York, and made preparation for prosecuting supplementary soundings on the coast of New Jersey.

For hydrographic work on the west side of Pamplico Sound, opposite to Hatteras Inlet, eighteen large signals were erected, and nine stations on shore were occupied. The general statistics are:

Miles run in sounding	610
Angles measured	3,355
Number of soundings	33,334

The work was closed for the season in the vicinity of Shoal Point, below which the hydrography of Pamplico Sound is complete. The past season was very unfavorable in respect of weather, and progress was in consequence much hindered. It is hoped that the remaining part of the hydrography may be completed in another fair working-season.

Lieutenant Handy was assisted in the operations of the hydrographic party by Masters W. P. Ray and F. H. Lefavor, U. S. N.

SECTION V.

ATLANTIC COAST AND SEA-WATER CHANNELS OF SOUTH CAROLINA AND GEORGIA, INCLUDING SOUNDS, HARBORS, AND RIVERS.—(SKETCH No. 10.)

Topography of Bull's Bay and vicinity, S. C.—In continuation of the work of the preceding season, Assistant W. H. Dennis, with his party, in the schooner Caswell, resumed field-operations on the 20th of December, 1874, at a point about a mile below Cape Romain. From thence the detailed survey was extended southward and westward, and at the close of the working-season in this section was joined at Sullivan's Island with the limits of a survey made in 1854. Soundings were made as the topography advanced, and these, plotted on separate sheets, show the hydrography of the inside water-passages within a stretch of thirty-two miles coastwise. The two plane-table sheets represent the shores of Bull's Bay, including the surface-features adjacent to Harbor River and Five Fathom Creek; Bull's Island, Caper's Island, and Price's Inlet, which separates them; Dewees' Island and Long Island, separated by Dewees' Inlet; and generally the topographical features between the coast-line and the main public road passing from Georgetown to Charleston, S. C. "The character of the topography is similar to that of the southern coast generally in this section—a line of sea-islands, with some fast land, backed by marshes three or four miles in width, and traversed in all directions by many rivers and creeks. The margin of the mainland bordering on the marshes is generally cultivated, the remainder being pine-barrens."

Assistant Dennis was aided in the field by Messrs. S. N. Ogden and W. S. Bond. The survey

was closed on the 1st of June, when the schooner Caswell was dispatched from this section and laid up at Norfolk. The following is a synopsis of the statistics of work:

Shore-line surveyed, miles	529
Marsh-line, miles	10½
Roads, miles	129
Area of topography, square miles	155
Miles run in sounding	421
Angles measured	3,286
Number of soundings	51,481

Assistant Dennis is now making preparation to resume field-work in Section I, under which head his occupation of the summer of 1874 has been mentioned.

Sea-encroachment at Hunting Island, S. C.—The topographical features of the north end of Hunting Island, which were mapped in the careful survey of 1859, could all be recognized some years after that date. About the year 1867, however, the sea, urged by a violent gale, broke through the beach opposite to a small creek near the site of the old light-house, and during subsequent years the encroachment has not ceased. In order to determine the amount of change, Mr. Charles Junken was detailed at the end of June of the present year to make a careful resurvey of the north end of the island. The results show that since 1859 the firm land of the north end to the extent of two-thirds of a mile has been washed away, and a channel with six feet of water at low tide now traverses a part of the island that was then covered with large trees. This channel, moreover, being bounded by an extensive sand shoal, that replaces what was formerly the north end of the island, is now the outlet of Johnson's Creek.

Mr. Junken found by examination that the other channels into Saint Helena Sound have not been influenced by the wearing-away of the north end of Hunting Island. Some changes have occurred in the main ship-channel, but only such as to make it expedient to re-arrange the buoys. As soon as practicable, the hydrography of the vicinity of Hunting Island will be examined.

Hydrography of Savannah River, Ga.—In my preceding report, mention is made of the shore-line survey of Savannah River, and of an examination of the currents, made at the request of the city authorities of Savannah, and important as the basis of plans for improving the channel. Means not being available for conducting the hydrographic resurvey at the same time, that work was deferred until the present season.

Lieut. J. M. Hawley, U. S. N., assistant in the Coast Survey, with his party, in the schooner G. M. Bache, sailed from Brooklyn, N. Y., on the 19th of December, 1874, but, in consequence of much bad weather on the passage and continuous rain after reaching Savannah, found it impracticable to commence operations until the 20th of January. A tide-gauge was established at the outset, and the record of high and low water was kept up until the 8th of May, when the soundings were completed. The limit of the hydrography above is the upper end of Elba Island. From thence, down the stream, the river was sounded thoroughly to the bar; the bar was developed and soundings were extended eastward to a line about a mile outside of Tybee light-house. The weather until April was very unfavorable, seldom affording an entire day for hydrographic operations.

In reference to the changes revealed by his soundings, Lieutenant Hawley remarks:

"I found the channel of the river in general but little changed since 1866, as shown by the Coast Survey chart of that year. The shoal off the lower end of Elba Island, between Basket Beacon and South East Beacon, has increased slightly, and, as a result, the width of the channel is there somewhat reduced."

"The large shoal off Cockspur Island has grown in the direction of the channel."

"In the channel dredged east of Oyster Reef by the United States engineers, the depth at mean low water this season is between twelve and thirteen feet."

"During the spring, owing to freshets, the current was so strong as to overcome the flood tide entirely, and it was noticed that vessels did not swing to the flood, except when at anchor in Tybee Roads."

"Many of the pile obstructions placed in the river during the late war still remain, and impede the downward passage of alluvial matter."

Tidal observations were recorded at Savannah, at the western end of Long Island, and at Fort Pulaski. The general statistics of the work are:

Miles run in sounding	232
Angles measured	3,316
Number of soundings	24,974

After completing the hydrographic resurvey of Savannah River, Lieutenant Hawley returned to Brooklyn in the schooner Bache, and reached that port on the 24th of May. In the course of the season, in Section V, he was assisted by Ensign J. M. Wight and Ensign G. C. Hanus, U. S. N.

SECTION VI.

ATLANTIC AND GULF COAST OF THE FLORIDA PENINSULA, INCLUDING THE REEFS AND KEYS AND THE SEAPORTS AND RIVERS.—(SKETCHES NOS. 11, 11*a*, 11*b*, AND 12.)

Coast hydrography near Saint Augustine, Fla.—In previous operations by the party in the steamer Endeavor, the inshore hydrography of the eastern coast of Florida had been advanced to a line about midway between Fernandina and Saint Augustine. At the opening of the working-season of the last fiscal year on the northern coast, Lieut. R. D. Hitchcock, U. S. N., assistant in the Coast Survey, after passing a short period at the office in noting methods and processes applicable for hydrographic work, joined the party in the Endeavor, and assisted in service afloat, as was stated under the head of Section I in this report. In December, 1874, the vessel was refitted at New York under the supervision of that officer, and, before the close of the month, his party was in effective working order on the coast of Florida. Above Saint Augustine Entrance, soundings were resumed on the 2d of February, and the work was extended southward until the 10th of June, when operations were closed for the season at Matanzas Inlet. From the shore-line to seaward, the coast-approaches were developed to an average distance of about nine miles. In crossing the approaches to Saint Augustine Harbor, which was about midway in his project of work, Lieutenant Hitchcock found that the channel leading into that harbor had improved. A careful examination was made and a depth of ten feet at mean low water was found on the bar. The course of the channel at the entrance changes in accordance with the direction and force of the storms in that vicinity; hence the sailing-directions prepared by Lieutenant Hitchcock, and which were issued from the office in January, enjoin that strangers should not attempt to cross the bar without a pilot.

For prosecuting the inshore hydrography, seventeen signals were erected at intervals along the coast above and below Saint Augustine. Four stations were occupied on shore while soundings were in progress. Surface-currents were observed generally within the limits of work, and the tides were recorded at Saint Augustine while hydrographic operations were in progress.

The general statistics are:

Miles run in sounding	1,036
Angles measured	3,047
Number of soundings	15,296

Lieut. James Franklin, U. S. N., and Masters John Hubbard, H. C. Nye, and J. L. Hunsicker, U. S. N., were attached to this hydrographic party.

In March, Lieutenant Hitchcock, noticed from the deck of the steamer Endeavor, when about two miles and a half off shore and a little to the northward of Matanzas Inlet, a curious agitation at the surface of the water, which seemed to indicate the existence of a spring issuing from the bottom at a spot where the depth was found to be 21 fathoms. Near by and all around the place at which the action was so violent that the ship was thrown off, the depth was 9 fathoms, and the agitation at the surface was noticeable only within a circle of about 30 feet in diameter. The specimen of bottom brought up by a cast of the lead showed very clean, broken, small shells, but, no instruments being at hand for special observations at that time, the steamer passed on her course. On the 8th of April, the Endeavor was anchored at the same place, but no sign of agitation appeared in the water. It was noticed, however, that, at intervals of a few minutes, the water within the space of a few square feet, became bright yellow, and coincidently gave off a very strong

odor of sulphureted hydrogen. Blue mud and shells were found in twenty fathoms near one of the yellow patches, all of which took color quickly, and, after liberating gas as quickly, disappeared.

Next day, the surface was found in motion like boiling water, all being yellow within a circle of 30 feet, and giving off sulphureted hydrogen. The yellow water seemed to rise as in clouds from the bottom. Owing to haze, which obscured the signals on shore, the exact position of the spot could not be determined at either of the visits so far noticed; but, on the 30th of April, several hours of continuous calm and clear weather sufficed for its accurate determination and for securing specimens of the water and of the bottom. The odor emitted and the great agitation were on that day the same as had been previously observed, but the water was not in the least discolored. It was flanked to windward by white caps, giving it the appearance of a shoal, and it now appears that the place has been sometime avoided as such. While the water is agitated from the bottom, pieces of shells are thrown up from the center of disturbance, which seems to have a greater depth than any other spot in that vicinity. The surrounding lines of soundings, crossing the place in all directions, give an average depth in the vicinity of 9 fathoms, with 21 fathoms in the small "boiling spot."

Survey of Halifax River and eastern coast of Florida.—At a point ten miles below Mosquito Inlet, the detailed survey of the eastern coast of Florida was resumed in November, 1874, by Assistant Charles Hosmer, with a party in the sloop Steadfast. Above that point, the field-work was then continuous to Saint Augustine, but soundings had not been made to include the lower part of Halifax River and Hillsboro' River. Mr. Hosmer completed the hydrography of both, and pushed the detailed survey from Turtle Mound southward about twenty-five miles along the Atlantic coast, including, in his limits of work, the shores and wide expanse of water at the head of Indian River and the adjacent part of Mosquito Lagoon. The body of water last named was sounded out, and the detailed survey includes also the topography of its shores. Finding it impracticable to pass the sloop Steadfast through the "Haulover," a short canal projected some years ago for connecting Indian River with the inland water-passage to Halifax River, the vessel was transferred by land over the barrier at reasonable cost, and was laid up at the end of May in Indian River, to be available for prosecuting the work southward to Jupiter Inlet.

As a check on the triangulation done by his party, Assistant Hosmer measured a base of verification on the neck of land which divides Mosquito Lagoon from Indian River, and immediately north of the Haulover Canal. The line is nearly 2,300 meters in length, and the measurement was found to be in near accord with the length as computed through the triangulation.

Subassistant L. B. Wright was attached to this party, and mainly conducted the soundings. Assistant Hosmer was aided also by Messrs. J. De Wolf and T. A. Harrison. The general statistics of the work are:

Signals erected	31
Stations occupied	25
Points determined	50
Angles measured	344
Number of observations	3,590
Shore-line traced, miles	286
Roads, miles	31½
Area, square miles	99½
Miles run in sounding	346
Angles with sextant	3,638
Casts of the lead	35,052

Field-work prosecuted by Assistant Hosmer in the early part of the fiscal year has been noticed under the head of Section II.

Triangulation and topography of the Tortugas.—For this service, Assistant H. G. Ogden temporarily left his party while it was engaged at Tampa Bay, and sailed with Acting Master Platt in the steamer Bache from Egmont Key early in March for Key West, where arrangements were completed for determining the relative positions of the seven keys of the Tortugas group. On the 24th

of March, a base-line was measured on Loggerhead Key, and from it angular measurements were recorded on ten signals, to include in position all the keys and the reef to the southward of the light-house on Garden Key. The triangulation was closed at a check-base on East Key.

In this work, Mr. Ogden noticed that, although the theodolite was mounted as usual on stubs of wood driven eighteen inches deep in the coral sand, the instability of the sand was such that any lateral movement by the observer caused a perceptible change in the pointing of the telescope. Observations were recorded by Assistant Ogden for azimuth, but under disadvantages arising from the prevalence of high winds during the short period available for the work at the Tortugas; Polaris being, moreover, at elongation near sunset and sunrising.

The plane-table sheet returned by Mr. Ogden shows in detail the seven islands in the Tortugas group, of which Loggerhead Key is the largest. Fort Jefferson, on Garden Key, affords a good landmark, and the harbor is well protected by the outlying reefs. North Key, Northeast Key, and Southwest Key, as represented on old maps, have no existence now, not being bare even at low water. Bird Key, East Key, and Loggerhead are partly covered with a growth of cedar. The others, excepting Garden Key, are merely sand banks, of which the outlines change with almost every gale.

Acting Master Platt, with his hydrographic party, in the steamer Bache, effectively co-operated in means for the triangulation and topography. For the uses of the sounding party, Mr. Ogden determined thirteen points. The ordinary statistics of his work in that vicinity are:

Stations occupied with theodolite	9
Angles measured	67
Number of observations	1,476
Miles of shore-line traced	7¼

Assistant Ogden completed the survey of the Tortugas on the 9th of April, and a week afterward rejoined his party on the shores of Tampa Bay.

Hydrography of Tortugas Harbor and Reef.—When the plane-table work was complete, and tracings had been made for the use of the hydrographic party, Acting Master Robert Platt, in charge of the steamer Bache, landed Assistant Ogden and his instruments at Egmont Key, and returned to prosecute soundings in Tortugas Harbor. That work was taken up on the 21st of April, and was completed on the 14th of May. The statistics are:

Miles run in sounding	367
Angles measured	2,990
Number of soundings	24,953

The chart plotted from soundings made this season at Tortugas Harbor and Reef essentially completes the hydrography of the Florida Reef.

The steamer Bache returned to Baltimore early in June, and, after being refitted, was placed in charge of Lieutenant-Commander Kennett for hydrographic service on the northern coast. The work conducted by that officer will be noticed in my next report.

Survey of Tampa Bay, Fla.—For extending the triangulation, and prosecuting the topographical and hydrographic survey, Assistant H. G. Ogden had his party in readiness early in November, 1874; but, as yellow fever then prevailed along the West Florida coast, the schooners Speedwell and Agassiz were not moved into Tampa Bay until the middle of the month following. The last-named vessel was placed in charge of Subassistant Joseph Hergesheimer, and was provided with means for sounding the waters within the limits of field-work.

The triangulation was resumed at Point Pinelos, and was extended northward to include old Tampa Bay and Hillsboro' Bay. Of old Tampa Bay, the shore-lines were traced and the plane-table survey was completed, leaving for the operations of another season the detailed survey of the shores and soundings in Hillsboro' Bay.

In preceding seasons, the hydrography of the main body of Tampa Bay had been advanced above the entrance on the Gulf, and upward to Gadsden's Point. Mr. Hergesheimer took up in February the hydrography of Palmasola Bay, Terraceia Bay, Little Manatee River, and Bishop's Harbor, and in those waters completed soundings by the middle of March. After that date, and

until the close of the season, his party was employed in the hydrography of Tampa Bay, in which soundings were also completed. Assistant Ogden left Egmont Key on the 12th of March for service which has been noticed under a preceding head. Returning in the latter part of April, he conducted the several branches of work in the survey of Tampa Bay, and closed operations on the 31st of May. The two vessels were then moved to Manatee, and there the hands who had been employed in the vicinity for the season were discharged. The schooner Speedwell was dispatched on the 10th of June for Baltimore, and was there refitted for other work.

Assistant Ogden was efficiently aided in the triangulation by Mr. H. F. North. The plane-table work was prosecuted by Mr. D. B. Wainwright, and is contained on four sheets. Sub-assistant Hergesheimer was aided in the hydrographic survey by Messrs. G. A. Morrison and W. B. French. At the outset of the season, this party assisted in erecting signals for the triangulation.

Tides were observed at five stations while the soundings were in progress, the results found by each of the tide-gauges being referred to a bench-mark at Egmont Key. Soundings made this season develop in position a number of shoals and rocks in Tampa Bay. About two miles southwest of Gadsden's Point, the steamer H. M. Cool was wrecked, in the season preceding the survey, on a ledge of rock which Assistant Ogden's survey proves to be several acres in extent, and marked by a number of sharp peaks, on one of which the depth is only four feet at low water. The existence of this ledge was not known previous to the wreck here mentioned.

During the early part of the season, the weather was very unfavorable for field-work in this section. After the 1st of May, squalls and showers recurred almost daily, but less impeded the progress of the parties, as the boats were started at daylight, and the rain commonly fell only in the afternoon. The statistics of the work are:

Signals erected	67
Stations occupied with theodolite	17
Angles measured	94
Number of observations	3,443
Shore-line surveyed, miles	219
Creeks and ponds, miles	30½
Roads, miles	9½
Marsh-outline, miles	18
Area in topography, square miles	102
Miles run in sounding	895
Sextant-angles	6,890
Casts of the lead recorded	69,434

Forty-eight points were determined in position by the measurement of horizontal angles.

Field-work previously done by the party of Assistant Ogden has been mentioned under the head of Section II.

Hydrography of Tampa Entrance and its Gulf approaches, Fla.—This work was commenced by Acting Master Robert Platt, U. S. N., with a party in the steamer Bache, on the 18th of December, 1874, and was completed in the middle of the following March. Bad weather generally prevailed while the survey was in hand. The steamer was very often stopped and anchored in consequence of fogs. Smoke along the coast and frequent winds also impeded progress in the soundings.

The hydrographic sheet shows the depth of water and character of the Gulf approaches for fifteen miles abreast of Tampa Bay, and from the coast-line westward to a limit of about five miles. The two channels were developed, and also the outlying dangers. Acting Master Platt found on the North Bar 21 feet of water at low tide and 19 feet on the Southwest Bar. The channels are straight and plain, and the anchorage is safe and well protected from heavy gales. During the period occupied by the party in this survey, there were no local pilots about Tampa Entrance, and no fresh water was to be had nearer than Manatee River. Renewing supplies from a point so far from the ground of work, of necessity delayed the prosecution of the hydrography. The statistics are:

Miles run in sounding	400
Angles measured	1,876
Number of soundings	17,564

Mr. J. B. Adamson served as aid in this party. After closing the hydrography, Acting Master Platt afforded transportation in the steamer Bache for Assistant Ogden. The vessel left Tampa near the middle of March, and co-operated in the survey of the Tortugas, as already mentioned.

Hydrographic work done in the course of the summer of 1874 by the party in the steamer Bache has been described under the head of Section I in this report.

Tidal observations.—The self-registering gauge set up at Saint Thomas, West Indies, by Colonel Thülstrüp, continues in operation, and periodical receipts from the observer, Mr. T. Kruse, show an uninterrupted series. It is desirable that the record should be maintained until November of the present year, as means will then be afforded for comparing the tides of Saint Thomas with the tides observed on the southern coast of the United States.

SECTION VII.

GULF COAST AND SOUNDS OF WESTERN FLORIDA, INCLUDING THE PORTS AND RIVERS.—(SKETCH No. 13.)

Topography and hydrography between Pepper Keys and Ocilla River, Fla.—The work of the season ending with June, 1874, on this part of the Gulf coast, determined points for the plane-table survey and inshore hydrography. Assistant F. W. Perkins had arranged to proceed southward early in November, after closing service which has been mentioned in Section I of this report; but, on account of yellow fever in southern ports, the organization of his party was delayed until the 8th of December, when the schooner Torrey was in readiness for work at Cedar Keys.

The stretch of coast included within the working limits of this party is low and marshy. On the land-side, the line of woods in some places is only a quarter of a mile from the water-line; in others, the forest is a mile distant, and, except at high tide, great mud flats impede the approach to the coast in boats. At several places, four miles off shore, the depth is only six feet at mean low water. Difficulties encountered by the party in prosecuting this work are thus referred to in the final report from the field: "The low flat woods, devoid of prominent features distinguishable at a distance, and consequent restriction in the placing of signals for angular measurements, a wide barrier of deep, soft mud impeding at low water the movements of the sounding boats as well as transfers of the plane-table party, and the necessity of working waist-deep on the overflowed marsh, have called for the employ of many expedients, but most of the hindrances were such as to be overcome simply by perseverance and endurance in the party."

As the first two months of the season were very unfavorable, being, rainy, stormy, or foggy, the results of the work are evidence of constant energy. Four topographical sheets returned from the party represent about seventy miles of the Gulf coast, and, within a belt of several miles, the courses of numerous streams, amongst which are the Steinhatchee River, Fenholloway River, Econfenee River, and Ocilla River, the roads adjacent to the shore, and in detail the intervening firm land, wooded areas, and marsh. The aggregate statistics are:

Shore-line surveyed, miles	124
Rivers and creeks, miles	171
Roads, miles	44½
Area of topography, square miles	104

Soundings were prosecuted at all favorable intervals between the 30th of December, 1874, and the 23d of June last. The results on four sheets show the inshore hydrography of the Gulf coast between Pepper Keys and the mouth of Ocilla River. The channels of that and other rivers already named were also developed. In general, the lines run in sounding the Gulf waters terminated at the depth of eighteen feet. The curve of that depth, as traced on the hydrographic sheets, is ten miles from the shore-line in some places, but on the average not much beyond seven miles. A heavy growth of grass springs up from the muddy bottom. The coral crops out frequently, and that formation is nowhere probably more than a few feet below the surface of the mud. Assistant

Perkins reports that anchorage is good in the offing, and, except near the points and capes, sufficiently smooth for the safety of vessels in almost any weather.

Shore-signals being impracticable for the hydrography, tripods about thirty feet long were made of scantling, launched from the vessel at suitable positions off shore, and properly weighted. Several signals of this kind were set in a day, and determined by angular measurements, while the soundings were in progress. Tides were recorded for each half-hour during a month, day and night, at a station on Pepper Key. The hydrographic statistics are:

Miles run in sounding	1,711
Angles measured	7,652
Number of soundings	40,721

The results of the work done by this party practically illustrate the terms in which Assistant Perkins commends the earnestness and endurance of his aids, Messrs. J. F. Pratt, F. W. Ring, and A. G. Pendleton.

Hydrography near Cape San Blas, Fla.—On the 8th of November, 1874, a hydrographic party, in the schooner Silliman, was organized under the charge of Master Kossuth Niles, U. S. N., assistant in the Coast Survey. As soon as practicable, the vessel was refitted at Jersey City, and arrived at Apalachicola late in December. Continuous fog during seven days deferred active operations until the 2d of January.

Inshore of Saint George Island, a tide-gauge was established at a station opposite to the light-house and another at West Pass. Mr. Niles, noticing a slight difference in results, determined mean low water by day and night observations for one month at the last-mentioned station, and applied the result as best suited for the adjustment of soundings to be made by his party. Two sheets were projected, to represent, when filled, the hydrography of the Gulf coast from Saint George light-house northward and westward to Saint Andrew's Point, and including the vicinity of Cape San Blas and the sounding of Saint Joseph's Bay. Signals for the work were set up and determined in January, when the weather was unfit for operations afloat; but, in the frequently recurring fogs of that and the month following, it was found expedient to observe with two theodolites at shore-stations while soundings were in progress. For the survey off the shoals off Cape Saint George, one theodolite was used at Cape Saint George light-house, and the second at a station on Saint Vincent Island. Subsequently, for developing the shoals off Cape San Blas, the instruments were used in conjunction at the cape light-house and at Indian Pass. By taking advantage of all favorable times, the hydrography was extended to Cape San Blas by the middle of April, and, with improved weather, the vessel was then anchored under the cape. Two observers were placed on shore with theodolites, and the shoals off the cape were surveyed. May was favorable for hydrographic work, and during that month Saint Joseph's Bay was sounded. The level of mean low water there was derived from day and night observations, continued through two weeks at a tidal station on the west shore of the bay. Early in June, the bar was developed by soundings, and the hydrography of the Gulf coast was afterward extended to include the approaches of Saint Joseph's Bay, between Cape San Blas and Saint Andrew's Point. The schooner Silliman returned to Apalachicola on the 26th of June.

Masters H. O. Rittenhouse, Alex. McCrackin, and H. W. Schaefer, U. S. N., rendered effective assistance in the hydrography, and their zeal and intelligence in the service are specially commended in the concluding report on the operations of the season by Master Niles. The statistics of the work are:

Miles run in sounding	728
Angles measured	3,661
Number of soundings	42,687

In the course of the season, the observers in the party determined thirty-five shore-stations, and measured angles with theodolites for nearly fifteen hundred positions on sounding-lines.

Triangulation, azimuth, and magnetic observations in Georgia.—Assistant F. P. Webber occupied Pine Log Mountain, in Northern Georgia, in July, 1874, and completed angular measurements with the theodolite at that station on the 17th of September. The party was then transferred to Lavender Mountain, which lies about thirty-seven miles to the westward, where observations, after

some days' hindrance from haze and smoke, were resumed on the 10th of October, for the determination of latitude as well as for advancing the triangulation. On seven nights previous to the 4th of November, 161 observations were recorded with twenty-eight pairs of stars. Azimuth-observations were made subsequently, thirty sets of twelve repetitions, each being recorded for the value of the angle between Polaris and a signal at Coosa Station. Mr. J. H. Christian, aid in the party, made time-observations. Magnetic observations for declination, dip, and intensity were made at Pine Log Mountain by Mr. Christian and at Lavender Mountain by Mr. Charles Tappan. The measurement of horizontal angles was completed at Lavender on the 31st of January. While that work was in progress at favorable intervals, the time unsuitable for observing was occupied in computations for latitude, time, and azimuth, and in duplicating the field and astronomical records. After the opening of October, this season proved to be particularly unfavorable for operations, the prevailing haze of autumn being succeeded by continuous rains and cold weather. Early in February, Mr. Webber stored his camp-fixtures at Rome, Ga., in view of resuming field-work with as little delay as possible in the spring.

John's Mountain, to the northward and eastward of Lavender Station, was occupied by the party early in May of the present year, and the observations were completed there in time to admit of the transfer of the party to Indian Mountain by the middle of June. The general statistics of the season in triangulation are:

Primary stations occupied	3
Horizontal angles determined	69
Vertical angles	44
Number of observations	9,584

At the opening of the present season, Subassistant F. D. Granger joined the triangulation-party. The advance of the work westward to a line within view of Lookout Mountain is there met by some difficulty in the likelihood, that, in order to pass that high ridge, it might be necessary to occupy another station at its eastern approach, for the determination of Gulf Point and Brandon, two positions on the Lookout Mountain Range. A like difficulty was to be expected on the western side of the ridge. The question thus pending at the opening of the present season was committed to Assistant S. C. McCorkle, whose work will be mentioned under the next head.

While employed at Lookout Mountain, Mr. Christian, aid, when overtaken by a tornado in June, was seriously injured by an uprooted tree which was hurled against him.

Primary triangulation (Sketch No. 9).—As stated in my report for last year, the party of Assistant C. O. Boutelle was encamped in June, 1874, at Grassy Mountain, in Pickens County, Ga. The theodolite-station there being about 3,300 feet high, and thirty-five miles distant from any railway-station, arrangements for observing involved much personal discomfort, and the labor incident to the construction of a road several miles long.

Magnetic observations were recorded at Grassy Mountain between the 12th and 31st of July. At the same time, angular measurements were made on seven distant signals with the new 20-inch theodolite, which Mr. Boutelle reports as being satisfactory in regard to precision, and as saving much time in easy adjustment, due to the facilities afforded by the peculiar construction of the iron stand of the instrument.

Observations by zenith-distances for differences of level were made in the usual manner.

At Skitt Mountain, which was next in order occupied, eastward of the preceding station, the measurement of horizontal angles and observations for magnetic declination and intensity were recorded between the 14th and 31st of August. Vertical angles were measured for determining the relative heights of the outlying stations. At this station, Mr. Boutelle noted also the approximate direction of each of the prominent mountains that could be identified as means for correcting in future the State map. Twenty-six points, chiefly mountains, were thus added for such revision, exclusive of the stations occupied by his party for actual triangulation.

Assistant Boutelle transferred his party in the first week of September to Currahee Mountain, Habersham County, Ga., and there established also an astronomical station. Observations for horizontal and vertical angles were begun at Currahee on the 17th of September, but their completion was delayed by smoke until the 21st of November. Ten signals were observed on. Thirty-

one subsidiary points were approximately determined in direction, and noted separately, as data for future reference in constructing a State map. One of the signals observed on from Currahee Station was sixty-two miles distant.

Azimuth was determined by 198 observations on Polaris within three hours of elongation.

For latitude, 44 pairs of stars were observed by the aids, Messrs. H. W. Blair and J. B. Boutelle, with zenith-telescope No. 3, in the course of three weeks in October, by 223 measurements on seventeen nights. Local time for latitude and azimuth-observations was obtained with Transit No. 11. The micrometer-value and level-divisions were found by the aid, Mr. Blair. The general statistics of the primary triangulation prosecuted this year northeastward from the Atlanta base-line are:

Stations occupied	3
Angles measured	20
Number of observations	2,158

When observations were closed at Currahee Station, Assistant Boutelle sent Mr. Blair to Lawrenceville, where the theodolite was mounted on the observing-tripod at Academy Hill for perfecting the measurement of horizontal and vertical angles immediately connected with the base-line. This service was completed on the 18th of December.

For extending the triangulation northward and eastward, Assistant Boutelle had conducted a reconnaissance in order to preserve advantages afforded for stations by the Blue Hill Range, and avoid the disadvantage of occupying higher mountain-tops in the region of the Alleghanies. The three stations selected, and the signals at which were observed on from Currahee, are Paris, Mauldin, and Pinnacle in the mountain region of South Carolina. In May, the triangulation-party transferred the instruments to a station on Blood Mountain, where observations were in progress at the close of the fiscal year, June 30, 1875.

Reconnaissance in Alabama.—In advance of resuming triangulation for determining points westward of those last occupied in the vicinity of the base-line near Atlanta, Ga., Assistant McCorkle was assigned to select stations that would connect properly with the work of Assistant Webber at Lavender and John's Mountain.

Crossing the State boundary of Georgia, the examination for stations was continued in Northern Alabama as far as Aurora in the northwestern part of Etowah County. This point is more than a hundred miles distant from the Atlanta base-line. Signals are now in place on Brandon and Gulf Point, intermediate between Aurora and John's Mountain, which last-named point was occupied by the party of Assistant Webber in the latter part of the present fiscal year. Assistant H. Anderson accompanied Mr. McCorkle on the reconnaissance. The region through which he passed affords no facilities for comforts in travel, and the service has in consequence been prosecuted under much personal discomfort. By the end of June, the examination was pushed as far west as La Grange in the vicinity of Tennessee River. West of Lookout Mountain, and through the entire tract between the Tennessee line and a line near Montgomery, Assistant McCorkle noticed evidence of mineral resources. Mineral springs were found in De Kalb, Saint Clair, and Blount Counties, and a white-sulphur spring noted for its qualities at Val Hermosa in Morgan County, Ala.

Reconnaissance.—To meet requirements in the State of Kentucky for geographical points on which to base the geological survey now in progress, Assistant R. E. Halter was assigned to the field early in July, 1874. After a personal conference with Prof. N. S. Shaler, State geologist, the examination was begun near Cincinnati. In advancing up the Ohio River, the country on both sides was included, but is reported as unfavorable for triangulation. Mr. Halter readily found a site suitable for a base-line, but no distant points were in view, and no scheme of triangles with sides of ordinary length was found practicable. In exceptional cases, a line of sight ten or twelve miles long was found, coincident with the course of a valley; but, in general, the connecting-points were only three or four miles apart. The reconnaissance was extended through Jackson, Pike, Scioto, Meigs, and Vinton Counties; and then south of the Ohio in the vicinity of Big Sandy River, in parts of Carter, Boyd, and Lawrence Counties in the State of Kentucky; and through Wayne and Cabell Counties in West Virginia. The region traversed is hilly and heavily timbered, especially in Kentucky and West Virginia, and affords no facilities for the ready transfer of instruments from station to station.

Assistant Halter returned from this section late in September.

Late in June of the present year, Prof. W. Byrd Page personally conferred at the office in regard to the requirements for effective triangulation in advance of taking the field near Cumberland Gap, a site of work indicated by the State geologist, and which will be occupied during the early part of the present fiscal year by Professor Page.

SECTION VIII.

GULF COAST AND BAYS OF ALABAMA AND THE SOUNDS OF MISSISSIPPI, AND OF LOUISIANA TO VERMILION BAY, INCLUDING THE PORTS AND RIVERS.—(SKETCH No. 14.)

Mouths of the Mississippi.—With the view principally of furnishing information for the commission appointed to examine plans for improving the outlets of the Mississippi River, subsequently replaced by a board of engineers appointed by the President of the United States, and of which board Prof. Henry Mitchell, Assistant in the Coast Survey, is an associate member, his party in the schooner Research reached Pass à Loutre on the 12th of December, 1874. The illness of the sailing-master, however, delay in the arrival of a substitute, calms on the passage south of Norfolk, and adverse winds, had consumed much of the time during which the commission awaited the co-operation of the party. Under advice of Mr. Mitchell, who returned north when preliminary deliberation was closed at the delta, Assistant H. L. Marindin, and the aid, Mr. J. B. Weir, remained, and prosecuted physical researches during the early months of the present year with the party in the schooner. These operations, as far as then practicable with the means at hand, were closed in March, and the schooner Research returned to New York. Meanwhile, a special appropriation had been voted by Congress for deepening the South Pass of the Mississippi, and, to meet the prospective requirements of the board of engineers, Assistant Marindin was detailed to proceed immediately by land to the delta, and to hasten the return of his vessel. Pending the arrival of the Research, the physical hydrography was resumed and prosecuted by Mr. Marindin, with assistance afforded by Mr. Boyd, who detached from his party the schooner Varina and a working force in charge of Subassistant Andrew Braid. The schooner Research arrived at the delta on the 30th of April, and, the party being thus re-enforced, observations upon currents, tides, and densities of water at the river-outlets were pushed without intermission until the end of June. Good observations were obtained at the three passes, and notably at South Pass, which will be valuable for comparison with series recorded as the work advances in the construction of jetties. These records, it is hoped, may furnish data for a physical history of the effects artificially wrought by expedients for deepening the water on the bar of the Mississippi. The preliminary report by Professor Mitchell (Appendix No. 11) describes the method by which he proposes to formulate the results of observation. At the Head of the Passes, observations were made in order to show in what manner the main stream separates as it approaches the passes, and the relation of the mud bank at the head of South Pass in this distribution of the main stream into several channels.

While weather was unfavorable for boat-work in the spring, Assistant Marindin, aided by Mr. Bion Bradbury, occupied the time effectively in setting up signals along the shores of South Pass. After his return, the shore-lines were carefully traced throughout, and subsequently the bed and channel of that pass were thoroughly developed by numerous soundings. An abstract appended to the field-report shows that the density of the water at the junction of the Mississippi with the Gulf of Mexico was tested by 203 observations. Amongst the details of the physical survey were determinations giving six profiles of sections, and currents along fifteen lines were determined by free floats. The general statistics are:

Angles for determining currents	1, 749
Current-observations recorded	2, 924
Miles run in sounding	268
Angles measured	5, 843
Number of soundings	21, 646

Operations in the physical survey were much advanced by the co-operation of the hydrographic party in the steamer Blake, under Lieutenant-Commander Sigsbee. During May and June, Mr.

Marindin employed, by the courtesy of Capt. Ed. A. Freeman, the steamer John A. Dix, and a launch, temporarily assigned by the Navy Department, for lines of soundings off the bar. These lines radiate from the delta, and connect as inshore hydrography with soundings made off the delta by Lieutenant-Commander Sigsbee.

Under the immediate direction of Assistant Marindin, the special hydrographic survey at the Head of the Passes was prosecuted by a party in charge of Subassistant Braid. As the prospective operations in engineering required, the ratio of discharge was determined by observations at the junction of Bayou Grande and South Pass with a view to the closing of the first-named outlet. Mr. Marindin measured sections above Bayou Grande in South Pass, also in the bayou, and in the pass below it, and at each ascertained the discharge of water per hour on the 4th of June of the present year. The result showed that the discharge through Bayou Grande was twenty-two per cent. of the volume emitted by South Pass above the bayou. In the pass below the bayou, observations were made also for set and drift of current.

Sections were measured on the 22d of June at Cubitt's Crevasse and the Jump. The former is a breach 2,700 feet wide, and with a maximum depth of 132 feet; but the water quickly shoals beyond the mouth of the crevasse, the depth in the course of a few hundred feet not being more than five feet at an average. When these observations were made, the surface of the river was about two feet above the extreme low-water stage. At the Jump, the section across measured 642 feet, and the maximum depth was 56 feet.

The shore-lines of the pass with those of the Head of the Passes, and the outline of lumps at the bar, were traced by means of the plane-table, and the statistics show an aggregate of thirty-four miles.

At the Head of the Passes, Mr. Marindin made sets of free-float observations on fifteen different lines, to determine locations for the spur-jetties proposed in the engineering operations of Mr. Eads for diverting part of the water from either the Southwest Pass or Pass à Loutre into South Pass.

After the close of work at the mouths of the Mississippi, at the end of June, the schooner Research underwent repairs, made necessary by exposure to the extreme heat in that month, and was then dispatched for New York. Assistant Marindin immediately engaged in the computations and other office-work pertaining to the several operations of the physical survey. Transcripts of all the data gathered in the physical survey will be forwarded at an early day to the War Department.

Hydrography, Gulf of Mexico.—Commander John A. Howell, U. S. N., assistant in the Coast Survey, with the hydrographic party in the steamer Blake, left New York on the 6th of November, 1874, and in the course of a fortnight arrived at New Orleans.

Under the direction of a board of commissioners, appointed by the President of the United States, to consider plans for improving the navigation at the mouth of the Mississippi, several weeks were employed by the hydrographic party in work outside the bars of the several passes, and in co-operating for the advancement of the physical survey, respecting which an outline was given under the preceding head.

Commander Howell having been transferred by the Navy Department to duty in the Naval Academy at Annapolis, as stated under Section I, Lieut. Commander C. D. Sigsbee, U. S. N., Assistant in the Coast Survey, succeeded to the command of the steamer Blake on the 12th of December. After that date, and until the 26th of April, the party was engaged in running lines of soundings outside of the Mississippi delta in depths varying from ten to fifty fathoms. This work supplements the hydrography which was prosecuted in the course of the physical survey. Twenty-seven lines in all were run, averaging 120 miles in length, and radiating into the Gulf from the shallow water of the approaches to the delta. The temperature of the water, and also its density, were recorded at each of about five hundred soundings. At intervals until May, the party in the steamer assisted in the various operations of the physical survey at the mouths of the Mississippi, mention of which service was made in the notice of that work.

Early in May, Lieutenant-Commander Sigsbee ran a line of soundings in the Gulf of Mexico from Southwest Pass to the mouth of the Rio Grande, and another from the mouth of that river to the Tortugas. Wire and the Thomson apparatus, which, for his immediate purposes, had been modified

by Lieutenant-Commander Sigsbee, were used for deep soundings, and the results proved to be entirely satisfactory.

In reference to the lines run in the deep water of the Gulf, it is mentioned in the summary report that the specimen of mud brought up from a depth of 583 fathoms emitted a strong odor of sulphureted hydrogen. This was on the line between the Southwest Pass and the Rio Grande. On both of the lines, temperatures were observed, and specimens of the bottom soil, and of the water there and at the surface, were taken at intervals corresponding with the determinations of depth. The greatest depth found was 2,119 fathoms, on the line between the Rio Grande and the Tortugas. In the hydrographic registers, seven hundred observations for temperature are recorded, and three hundred for densities of the Gulf water.

The temperature-observations so far made lead to the inference, that, in general, the normal temperature of the Gulf water is about 39½° Fahrenheit, that temperature being reached at 350 fathoms, and remaining apparently constant to depths of 2,000 fathoms.

The general statistics of the work are:

Miles run in sounding	2,724
Angles measured	764
Number of soundings	761

In prosecuting hydrographic work in the Gulf of Mexico, Lieutenant-Commander Sigsbee was ably assisted by Lieuts. C. T. Hutchins, J. W. Hagenman, and J. M. Grimes, U. S. N.; by Master R. G. Peck, U. S. N.; and by Ensign W. E. Sewell, U. S. N. At the close of the fiscal year, Lieutenant Hutchins and Lieutenant Grimes were assigned to take charge of separate hydrographic parties for work on the coast of New England, near which Lieutenant-Commander Sigsbee will also be engaged in deep-sea soundings.

Survey of the Mississippi River at New Orleans, La.—The schooner Varina was refitted at New Orleans for the service of the party of Assistant C. H. Boyd early in November, 1874; but as yellow fever prevailed then in the city, the vessel was not moved until the end of that month, when the topographical survey of the vicinity of New Orleans was taken up. Two plane-tables were employed; and, with frequent weather-interruptions, the work advanced upward from a station about three miles below the city, where the detailed survey had stopped in the previous year. In the course of the season, the plane-table operations included the city of New Orleans and the towns of Algiers, Gretna, McDonoughville, and Carrollton, and both banks of the river from stations near the battle-ground to Kennerville, or about nine miles above Carrollton. The triangulation was extended from the town last named to stations several miles above Kennerville. All the field-operations in this quarter were retarded during December and months following until the 1st of March. The field-journal noted rain during some part of every day in January.

Late in March, Assistant Boyd, under special instructions, detached from his party Sub-assistant Braid, and co-operated also in person at the outset, for a minute survey of South Pass, reference to which was made under the last head. A triangulation then conducted through the pass determined in position forty-two points for guiding in the detailed plane-table survey. Returning to the site of his own field-operations, Mr. Boyd closed the river-triangulation for the season at the end of April, and made a reconnaissance of the Amite River region for stations that might serve to connect the survey of Lake Pontchartrain with that of the Mississippi above New Orleans. Assistant Boyd also ran lines of level (fourteen miles in all) to connect the Carrollton bench-mark, established in the survey of 1858 by the United States Corps of Engineers, with the bench-mark at the mint in New Orleans, to which last are referred the tidal records of the Coast Survey. Messrs. C. H. Van Orden and W. E. McClintock were attached to this party as aids. The work was discontinued on the 23d of June. Few soundings had been made in the river above New Orleans, as, when arrangements had been completed for such work, the emergency arose for the services of Mr. Braid in South Pass. The general statistics of work reported by Assistant Boyd are:

Signals erected	16
Stations occupied	21
Angles measured	182

Number of observations	3,072
Shore-line surveyed, miles	56
Creeks, miles	4
Roads, canals, levees, and streets, miles	870
Area of topography, square miles	78

The river-currents were observed at three stations, and tides were recorded daily at New Orleans throughout eight months. The topographical survey is comprised on three sheets, which will be inked as soon as practicable.

Triangulation in Missouri (Sketch No. 15).—This work was resumed by Assistant Boyd on the 15th of August, 1874, at a station on the south side of the Missouri River, about thirty miles west of Saint Louis. The chain of triangles laid out westward extends the work to the vicinity of Gasconade River. Signals have been set up in eight counties of Illinois and Missouri; and, of the stations already occupied, eight are in the immediate neighborhood of the parallel of latitude that passes through Saint Louis.

The triangulation done this year previous to the middle of October, when the party resumed work in another part of the section, extended the determination of points westward thirty miles, through a country thinly settled, and offering some obstacles that are not commonly met along the seaboard. All the ridges relied on for stations are densely wooded with hickory and oak, and, being nearly of the same height, their identification at a distance is difficult. Clearing lines for sight proved to be very laborious, and no lumber could be procured in the region for signals. In crossing the fifth principal meridian of the United States land-surveys, Assistant Boyd occupied a subsidiary station, and connected one of the marks on that meridian with his scheme of triangles. Another corner was identified eastward and northward of that line, and was brought into connection with his scheme of geographical points. The latitude and longitude of Saint Louis having been well determined since the period of the land-surveys in that part of the State, the two points referred to, as might be expected, do not accord on the local maps with results given by the geodetic work. The statistics of the triangulation are:

Signals erected	6
Stations occupied	9
Angles measured	56
Number of observations	4,032

Of the lines connecting stations, seventeen required clearing to admit of observing with the theodolite. As usual in work of this kind, a number of objects were observed on, additional to erected signals, the positions of which were to be precisely determined by means of angular measurements. Mr. Van Orden accompanied Assistant Boyd as aid in this work and in that noticed under the preceding head.

Reconnaissance in Wisconsin.—In order to provide for the systematic determination of points in the State of Wisconsin, a reconnaissance, conducted by Prof. J. E. Davies, was commenced at the opening of the fiscal year, as was mentioned in my last annual report. During the season, until October, 1874, and at intervals in the course of the winter and spring, the work was vigorously prosecuted through the region included between the Wisconsin River, below Grand Rapids, and the east bank of the Mississippi, between Black River and Prairie du Chien. Three chains of triangles were laid out, bounding that region, and making in the aggregate a belt of about 225 miles in linear extent. Some of the lines in the scheme are thirty miles long; but, in places where obstacles intervened, the lengths lessen to six and eight miles. The practicability of some of the lines is yet uncertain, but the scheme as presented, results from the patient examination in person of ground, in traversing which, Professor Davies traveled abou tnine hundred miles over rough or sandy roads, the stations desirable being of course in parts the most elevated and the farthest from social comforts. Windfalls, marshes, and uninhabited tracts fully tested, but they have not lessened, the interest of the intelligent observer who has enlisted in this work. In the spring of the present year, and in advance of the appearance of forest-leaves, Mr. Davies again took the field, with a view of improving the scheme of triangulation, which was provisionally marked out for including the region of Black River at a time when foliage had not fallen from the trees. Preliminary

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Page 47, paragraph 3, 12th line from top, for "350 fathoms," read "500 or 600 fathoms."

arrangements for such work include as conditions for ultimate success, that sites for base-lines should be available at suitable intervals in the triangulation. The ground to be measured, if not level, should be such that the measuring-bar shall in no case have an inclination of more than 6°, and the line should be so related to the nearest geodetic stations as to admit of connection with them by large angles. At intervals in the scheme of triangulation, it is desirable also that quadrilaterals should appear, if the reconnaissance shows that a chain of successive quadrilaterals is impracticable. The conditions here mentioned were kept in view in the operations of Professor Davies, and will be met as far as the difficulties of the ground allow. As now provisionally marked out, the three connecting chains of triangles will require as many bases of verification, determinations of azimuth at four stations, and of latitude at two points of the triangulation. The longitude of the university at Madison has been already determined.

Early in June of the present year, Professor Davies perfected arrangements for resuming field-work at Spring Green, near which, in the valley of the Wisconsin River, the plain seemed favorable as a site for a base-line about three miles in length. In the middle of the month, Assistant Richard D. Cutts reached Madison, and proceeded with Professor Davies to Spring Green. A site for the line was selected, the adjacent country was examined with reference to its connection with station-points, and reconnaissance was made for conducting the triangulation out of the valley. Assistant Cutts co-operated in the movements of the party during several days, and gave detailed explanations in regard to all the requirements for field-work, in particular the scheme of lines for emerging from the confined valley, and for connecting the base with the main triangulation. When he left Madison, at the end of June, to arrange for the operations of his own party, in Section I, Professor Davies was in readiness to occupy stations for the measurement of horizontal angles in the vicinity of Spring Green.

SECTION IX.

GULF COAST OF WESTERN LOUISIANA AND OF TEXAS, INCLUDING BAYS AND RIVERS.—(SKETCH No. 16.)

Hydrography of Aransas Bay and Musquit Bay, Tex.—For this duty, the schooner Bibb, after service which has been mentioned under the head of Section II, was refitted, and sailed from Norfolk on the 3d of December, 1874. The party reached Indianola, Tex., after a run of three weeks. As soon as practicable, Subassistant W. I. Vinal, who was in charge, proceeded to San Antonio Bay, and sounded a space near the western end to complete an interval in the operations of the preceding season. Stormy weather prevailed through the month of January. This hindrance, and the fact that by reason of her draught of water the schooner could not be used in extending the work further, constrained the engagement of a lighter of fifteen tons, by means of which Mr. Vinal completed the supplementary work in San Antonio Bay on the 21st of March. Frequent and heavy "northers," the extreme scarcity of fuel and of fresh water, and sickness amongst the crew retarded the operations. With weather somewhat improved after the equinox, the tender was able to prosecute work near the anchorage of the Bibb, and made satisfactory progress during April and May. By the 1st of June, soundings were completed through Musquit Bay, and about two-thirds of the upper part of Aransas Bay had been sounded out. The statistics are:

Miles run in sounding	635
Angles measured	5,156
Number of soundings	89,697

Subassistant Vinal was aided by Messrs. E. H. Wyville and E. B. Pleasants. Early in the season, Lieut. Richard Wainwright, U. S. N., was associated with the hydrographic party in the schooner Bibb. On the 1st of June, the charge of the party was transferred to that officer. Mr. Vinal then took in hand the details of office-work pertaining to his hydrographic operations in this section. Under the direction of Lieutenant Wainwright, the hydrography of Aransas Bay was completed by the end of June. His operations include, also, progress in the hydrography of Lamar Bay and Copano Bay, and the development of Saint Charles Bay up as far as the reef which traverses it from shore to shore.

The party of Lieutenant Wainwright will continue work in this section during the summer.

SECTION X.

COAST OF CALIFORNIA, INCLUDING THE BAYS, HARBORS, AND RIVERS.—(SKETCHES Nos. 17, 18, 19.)

Good progress has been made by the land-parties working in this section, and a large advance in hydrography. During the greater part of the fiscal year, the field-assistants, who have hitherto made the astronomical observations at stations on the Pacific coast, were absent as members of several expeditions sent by our Government to Asia and the South Pacific Ocean for observing the transit of Venus in December, 1874. The junior observers, mentioned in my report of last year as on that special astronomical service, returned in the spring and resumed their accustomed field-work. Assistant George Davidson, the principal observer in Japan of the December transit, was requested to improve the opportunity afforded by the distant voyage for recording magnetic observations while crossing the Pacific Ocean. As arranged, also, with that experienced observer in personal conference previous to his departure, he passed some weeks of the present year in India carefully examining systems of irrigation, with reference to provision for an acknowledged want in some of our great western valleys, Professor Davidson being himself a member of the commission appointed by the President of the United States to devise plans of irrigation for California. At the same time advantage was taken to note the methods in field-work for the geodetic survey of India, and generally the appliances and expedients as compared with our own resources for prosecuting the work of triangulation. In Egypt and elsewhere, Assistant Davidson gave attention to results gained in marine engineering, and has recorded the methods adopted in successful works of that character. The scarcity of harbors on the upper coast of California and on the coast of Oregon, must at an early day, in view of the increase of settlements, call for the construction of breakwaters at places capable of being so sheltered and affording good anchorage as harbors of refuge. For such prospective requirements, information has been gathered from all available sources in Europe, and, incidentally, the methods pursued there in the reclamation of tide-lands.

The comprehensive report presented by Professor Davidson, includes the results of his inspection of instruments of precision now used by European observers, a branch of research for which he is specially qualified. In the introductory part of this report, allusion has been made to the results obtained by Professor Davidson at the station occupied in Japan by himself and his aids for observing the transit of Venus. The details in regard to his operations for that service are given in Appendix No. 13.

Of the several Japanese officers who visited the transit-station of the Coast Survey observers at Nagasaki, Capt. Nawo-Yoshi Yanági, chief of the bureau of hydrography of the imperial navy, is regarded as one of the most learned men of Japan. From the naval station at Tokio he made the trip to Nagasaki for the sole purpose of witnessing and studying the operations of the party. After personally noting the processes for determining the difference of longitude by telegraph between Nagasaki and Tokio, the captain consulted Professor Davidson in reference to instruments, and requested him to procure and forward such an outfit for an observatory as would include means for rating the chronometers of the naval vessels of Japan, and serve for general purposes in astronomy. This first observatory in Japan will be erected in the extensive grounds of the imperial navy department at Tokio, and on the site occupied by Mr. Davidson for longitude-observations. At the joint request of Captain Yanági and other high officials of the government, the longitude-station at Tokio was connected by telegraph with the transit of Venus station at Nagasaki.

In passing through Europe, Mr. Davidson gave the orders of Captain Yanági for an astronomical clock with break-circuit attachments, at Berlin, and for the Hipp chronograph. A break-circuit chronometer will be sent from New York; and a meridian-instrument, of the form devised by Davidson, and made by Würdemann, will be forwarded from Washington. Mr. Davidson has consented also to arrange all the needful telegraphic apparatus, test the instruments as they are delivered by the maker, and furnish copies of papers descriptive of the field-uses of the several instruments, and in regard to methods of reducing the observations.

Proceeding now in geographical order, notice will be taken of the work done in each locality

to which parties have been assigned within the fiscal year on the Pacific coast. In the arrangement, mention will first be made of work done near the southern boundary of California, and the report on field-operations will close with an abstract of the results gathered on the coast of Alaska.

The operations of parties working near and along the coast to the southward of San Francisco were inspected in April last by Assistant Richard D. Cutts. With some, then at work with the plane-table, special conferences were held in regard to the delineation of the abrupt and high elevations that mark the topography of the coast adjacent to the Santa Barbara Channel, and for which the methods employed on the less rugged coast of the Atlantic would prove both too laborious and expensive After general consultation at San Francisco, in reference to these and other details of field-work, Mr. Cutts left early in May to return to Washington, but, at my request, remained a few days at Salt Lake City. There he examined the valley with reference to its facilities as a site for a base-line to serve in a chain of large triangles, for part of which, starting near the Pacific coast, reconnaissance has been made, as will be noticed further on in this section. The large experience of Assistant Cutts in field-work on both sides of the continent gives special value to the notes and observations which were filed at the office on his return from San Francisco.

Triangulation, topography, and hydrography at Newport Bay, near Point Lasuen, Cal.—In order to resume operations on the southern coast near Anaheim, Assistant A. W. Chase took passage, on the 25th of January, from San Francisco, but on his arrival found the entire region flooded, and railroad and stage communication cut off by high water. Early in February, however, he took up the survey near Newport, where he was joined at the end of the preceding month by Subassistant Eugene Ellicott and Mr. F. A. Lawson. Signals were erected for extending the work along the coast southward toward San Diego, and tidal observations were commenced to provide data for the adjustment of soundings on a chart of Newport Bay, the commerce of that region in wool and other products having recently attracted vessels from San Francisco. At the end of April the hydrography of the approaches and channels, the triangulation of the vicinity, and two plane-table sheets of the detailed survey had been completed. Early in May the party was discharged as the sum allotted for field-operations was then exhausted. Mr. Chase completed his records and computations by the end of the fiscal year, and is now engaged in extending the survey to include the shores of Santa Monica Bay eastward from Point Duma. The general statistics of the work done within the year previous to the end of June are, for this vicinity:

Signals erected	19
Stations occupied	15
Angles measured	108
Number of observations	1,746
Shore-line traced, miles	41½
Roads, miles	6
Area of topography, square miles	16½
Miles run in sounding	60
Angles measured, sextant	708
Number of soundings	5,514

Periods unfavorable for field-work and all incidental opportunities have been for some years improved by Assistant Chase for collecting objects of interest in archæology, geology, and natural history, in which studies he has maintained intimate relations as a correspondent with the Smithsonian Institution. At the instance of Prof. Spencer F. Baird, and in well-founded reliance on the discretion of Assistant Chase, full scope has been allowed for securing in time, and without cost, such objects within his reach as would be deemed worthy of the National Museum. His researches and contributions have already added much that will avail in compiling a history of earlier times for the coast of California.

Early in the fiscal year, Mr. Chase was occupied in extending the survey of the coast above Cape Mendocino, in regard to which, notice will be taken presently in this chapter.

Topography of Santa Cruz Island, Cal.—The detailed survey of Santa Cruz Island was prosecuted by Subassistant Stehman Forney during the summer and autumn, and until the 4th of December, 1874, when the party was disbanded for the winter. Mr. Forney employed the interval

until February in working up, at San Francisco, the field-observations and perfecting the plane-table sheets which had been brought from the field. His party was re-organized as early as the weather would permit, and resumed the detailed survey. Owing to the scarcity of fresh water in the region to which the work had extended early in the spring, temporary camps were used at sites near small springs in the interior of the island, and from these as centers of work the topography was advanced and joined with the details of previous seasons. Before leaving the west end of the island, Mr. Forney selected and marked a station at which signals on all the outlying islands of the Santa Barbara group will be in view under favorable circumstances.

Along the shore at Prisoner's Harbor, on the north side of the island, changes were observed, to which is probably due the loss of the point occupied for astronomical observations in 1852. The shell-mound on which the instruments were placed has been washed away by subsequent winter-freshets.

The field-report states that on the northwest and northeast ends of Santa Cruz Island terraces, supposed to mark old sea-beaches, are yet distinctly defined. Such features in topography have been frequently noticed on the main; and within the limits indicated for plane-table work along the coast the terraces there and elsewhere will be mapped as details of special interest in researches relative to the geology of the coast of California.

Santa Cruz Island is nearly twenty-five miles long, and has an average width of about four miles. The surface, though exceedingly rough, is well represented in the plane-table sheet by curves drawn for each 200 feet of successive elevation above the water-line. The highest point of the island is 2,410 feet above the level of the sea. On the lower parts of the surface, grass is abundant, and for some years has sustained a stock of sheep so considerable that fifteen to twenty thousand head have been taken from the island annually.

The detailed survey has developed several good anchorages and boat-landings additional to those heretofore resorted to, and the exact location of each of the fresh-water springs, some of which, when more generally known, will doubtless be of account to sea-going vessels.

The following synopsis gives the statistics of work in the concluding season of the survey of Santa Cruz Island:

Signals erected for triangulation	13
Shore-line surveyed, miles	32
Creeks, miles	6
Roads, &c., miles	39
Area of topography, square miles	41

At the close of the fiscal year, Subassistant Forney made preparation to take up the detailed survey of Santa Catalina Island.

Hydrography around Santa Cruz Island, Cal.—The work done in the summer of 1874 by the hydrographic party of Lieut. Commander H. C. Taylor, U. S. N., assistant in the Coast Survey, in the steamer Hassler, will be mentioned under a subsequent head in this section. When the season closed for operations abreast of the boundary-line between California and Oregon, the steamer returned to San Francisco, was promptly refitted, and commenced soundings in the vicinity of Santa Cruz Island on the 12th of November, 1874. The work was steadily pushed until the 19th of December. During the winter, Lieutenant-Commander Taylor and his officers completed and forwarded to Washington the charts and records of the season passed on the northern coast. The hydrography near Santa Cruz was resumed on the 19th of March of this year, and was steadily prosecuted onward and throughout June, when the work was essentially finished. Near the west end of the island, soundings were made last season by the party in the Hassler under the direction of Commander P. C. Johnson, and near the east end the approach had been developed previously in connection with the hydrography of Anacapa Passage. Joining with the limits of completed work, Lieutenant-Commander Taylor sounded the approaches of the north and of the south side of the island, making in the aggregate a belt of forty-eight miles in length and nearly six miles wide. Of the features developed, two of the most important are the well-marked submarine plateau extending from the north face of Santa Cruz Island, and a remarkable submarine cañon off the southwest corner

of the island. Commander Johnson, in sounding Santa Cruz Channel, found 100 fathoms with 40 fathoms on each side, and supposed the vessel to be directly over the head of a cañon that stretched directly to seaward, but time did not then allow of the development. In the course of the present year, Lieutenant-Commander Taylor found exceptional depths at places southward of Santa Cruz Island and some miles to eastward of the Santa Cruz Channel. Following the course indicated by large variations in depth, the cañon was traced to its head, and that was found at the position in which Commander Johnson had recorded the soundings before mentioned. In further reference to this remarkable depression in the sea-bottom, Lieutenant-Commander Taylor says:

"Commencing at about the middle of the southern part of Santa Cruz Channel, the cañon turns at once to the eastward and sweeps along parallel to the south shore of Santa Cruz Island for some miles, when it again turns southward and goes to the deep sea at a point a little east of Gull Island. It averages 300 fathoms in depth for the greater part of its length, with 40 and 50 fathoms on its seaward side. The bottom is rock and shells as far as the turn to seaward, where the ooze of the deep sea begins to show. This remarkable feature has been fully developed, as will be seen by the manuscript chart."

The statistics of hydrographic work in the vicinity of Santa Cruz Island are:

Miles run in sounding	715
Angles measured	6,182
Number of soundings	6,080

Lieutenant-Commander Taylor has been assisted in the operations of his party by Lieutenants Talcott, Courtis, Clover, Adams, and Tyler.

In order to further as far as practicable important researches conducted under directions from the Smithsonian Institution, the steamer Hassler and means at his disposal were temporarily used by Lieutenant-Commander Taylor in June for facilitating the movements of Mr. Paul Schumacher, agent of the Institution; and for the transfer of a scientific party under Dr. Yarrow, United States Army, attached to the exploring expedition under command of Lieutenant Wheeler, United States Corps of Engineers.

At Santa Barbara, on the 7th of June, Lieutenant-Commander Taylor relieved the ship Arkwright by passing the Hassler out to lead through the kelp, when it was feared that a shift of wind would throw the first-named vessel on shore.

The hydrographic party, when this report closes, is about completing work in the vicinity of Santa Cruz Island.

Triangulation across the Santa Barbara Channel.—Subassistant O. H. Tittmann, after his return from Japan, where he was of the party sent under the direction of Assistant Davidson to observe the transit of Venus in December, 1874, resumed field-work at Gaviota Station on the shore of Santa Barbara Channel. Heliotropes were stationed on San Miguel Island and on Santa Cruz, and angular measurements were made on them in connection with a signal at Santa Barbara, until June of the present year. The season was unfavorable, and the signals were consequently often invisible from the observing-station. Several partial series of horizontal angles were, however, measured, and astronomical observations were recorded successfully on four nights. Mr. W. S. Edwards was attached to this party as aid. In the course of a continuous spell of foggy weather, Mr. Edwards ran a line of levels from Gaviota Station down to the beach. The bench-mark established there will be referred to a tide-gauge, which it is the intention to put in operation when the party returns to this quarter in the course of the present year. The wharf now under construction will probably be completed in August, and will afford the facilities needed for tidal observations.

Hydrography of San Luis Obispo Bay, Cal.—As mentioned in my last annual report, Assistant L. A. Sengteller remained at San Francisco during the early part of the present fiscal year in consequence of a very serious accident, which disabled him for months from undertaking field-service. When at length able to sit up and move on crutches, his office-work was taken in hand and completed. Three plane-table sheets were inked and placed in the archives, with nineteen volumes containing the records and computations of his previous field-work. The office depository in San Francisco was carefully examined, and its contents were classified and arranged for convenient ref-

erence. In this duty, Mr. Sengteller was busily engaged during the winter. Finding himself able to take the field in the latter part of February, a party was organized, and prosecuted under his direction the hydrography of San Luis Obispo Bay. In that work, three sunken rocks were discovered and reported as dangerous to navigation. One of these, in fourteen feet water at mean low tide, lies a mile to the southward of Rocky Bluff; the others are in eighteen feet water, are about half a mile apart, and lie about a mile and a half southwest of Whaler Island, at the extremity of Point San Luis. All were carefully determined in position; ranges for avoiding the dangers were promptly furnished, and in May a "Notice to Mariners," in the usual form, was issued from the office.

The hydrography of San Luis Obispo Bay was developed to a line about three miles west of Point San Luis, so as to include the approaches to the bay from the northward. Soundings were extended to about the same distance eastward of the point. The curve of twenty fathoms was traced on the chart after its completion, and appears at varying distances from the line of mean low water, in some places being a mile and a half and at others four miles off shore.

Mr. F. Westdahl served as aid in the party of Assistant Sengteller. Soundings were commenced on the 1st of March and were completed at the end of April. The general statistics are:

Miles run in sounding	549
Angles measured	6,611
Number of soundings	19,679

For the adjustment of soundings, nineteen signals were erected on shore and determined in position by means of the theodolite.

Mr. Sengteller completed his office-work by the end of June, and then made preparation for resuming field-duty on the coast between Bodega Head and Point Arena.

Topography of Point Sur.—This survey for the uses of the Light-House Board was committed by my instructions to Assistant C. Rockwell in the latter part of January, and in expectation that means of transit could be readily had. Finding, however, that the light house tender was laid up for repairs, and wishing to avoid delay, a small vessel was engaged to move the party to the working-ground. That vessel proving unequal to the service, Mr. Rockwell engaged the steamer San Luis to put himself and the party and instruments ashore on the next trip of the vessel to San Diego. A storm from the southward detained the vessel two days in Monterey Bay, but she was off Point Sur on the morning of the 4th of March. The San Luis lay off all day under steam; but, finding it impossible to land the camp-fixtures and some of the instruments and tools, she passed on to San Diego, leaving Assistant Rockwell, who had gone ashore in the only boat that it was found practicable to land on the point. Two hands belonging to the party were carried off by the steamer. With the remaining hands, Mr. Rockwell took shelter in a deserted dairy-shanty, and, pending the return of the vessel, commenced next day and continued field-work with such instruments as he had taken on shore. He selected a site for a base-line, and marked points as stations for the triangulation. On the 17th of March, the steamer San Luis, on the upward passage, was again off Point Sur, but a northwest gale made it impossible to restore to Mr. Rockwell what was on board belonging to his party outfit. The articles were consequently left at Monterey, and finally were delivered on Point Sur by a small sea-going boat hired for the purpose. Unfortunately for the owners, while moored under the rock, after landing her cargo on Point Sur, the boat broke from her moorings and was dashed to pieces on the beach. Assistant Rockwell measured a base-line with a twenty-meter chain, and made a triangulation sufficient for the desired plane-table survey, which includes several miles of the coast adjacent to the point. The journal of occupation shows that at Point Sur the wind blew incessantly from the 10th until the 22d of March, and very frequently for shorter periods in the course of the season. The result of this topographical survey is a valuable map on a scale sufficiently large for any purpose of the Light-House Board. Bearings up and down the coast to numerous points in view were taken by Mr. Rockwell, and such details were included as were deemed indispensable for the selection of sites proper for a light-house and fog-signal. Owing to its peculiar shape, the hill presents difficult features with reference to the coast-lines of visibility. While the triangulation was in hand, two of the mountain-peaks back of

Point Sur were determined in position, and, both being sharply defined, they will, as landmarks, be of special use in prosecuting the offshore hydrography.

On the 21st of April, while Mr. Rockwell was at work near by, the steamship Ventura ran upon the rocks a mile north of Point Sur, and proved a total loss. The opinion is expressed in his report that the disaster could not have occurred if a fog-signal had been in operation on the Morro. From that which he occupied as one of his stations, he noticed outlying rocks and bunches of kelp to the southeast of the rock and at considerable distances off shore. He remarked that vessels, in rounding the point, ran too near; and such appears to be the custom in navigation at other points on the western coast not less marked by dangers in navigation. The statistics of work done in the survey of Point Sur are:

Signals erected	10
Stations occupied	8
Points determined	12
Angles measured	52
Number of observations	698

The topographical sheet of the Morro at Point Sur, on a scale of $\frac{1}{2500}$, shows by curves the successive elevations of five feet. These curves were carefully traced by means of the level. A second topographical sheet, on a scale of $\frac{1}{10000}$, shows the entire vicinity of the cape. The work depends on a measured base of 800 meters.

The party of Assistant Rockwell left Point Sur on the 13th of May, on the steamer Santa Cruz, and returned to San Francisco.

Shoal off South Farallon Island.—Late in June of the present year, Lieut. Commander H. C. Taylor, U. S. N., assistant in the Coast Survey, in charge of the steamer Hassler, while taking in coal at San Francisco, was informed of the existence of an unmarked rock near South Farallon light-house. Before resuming regular work near Santa Cruz Island, search was made, and the shoal was found at the reported bearing, but only about half a mile from the light-house. The depth found was six and a half fathoms, and, as reported, the sea breaks on it only in exceptionally heavy weather.

Noonday Rock.—In October, 1874, Lieut. Col. C. Seaforth Stewart, Corps of United States Engineers, provided means for increasing the depth of water on Noonday Rock, the position of which was determined some years ago by Assistant A. F. Rodgers of the Coast Survey. This danger was eighteen miles from the coast of California, and about three miles northwest of the North Farallon. As Fanny Shoal, its existence had been known; but there was much uncertainty in regard to its whereabouts previous to 1863. On the 2d of January, in that year, the ship Noonday, when the vessel by her reckoning was eight miles from the North Farallon, struck on the rock near midday, and within two hours sunk in forty fathoms.

When arrangements were complete for the operations proposed in submarine engineering, no suitable vessel could be procured at San Francisco, and the cutter Shubrick could not be spared from pressing duties in the light-house service. Under these circumstances, application was made to Lieutenant-Commander Taylor for the co-operation of his party in the steamer Hassler. The vessel accordingly left San Francisco on the 30th of October, and by nightfall a buoy was placed on the top of the rock, where the depth was found to be 20½ feet at low water.

Subsequently, Lieutenant Weeden, of the Corps of Engineers, in close examination, by the aid of a diver, discovered that the rock did not terminate in a single point, but in three, and that the depth on one of the peaks was only fourteen feet at mean low water. Measurements made by Lieutenant Weeden were embodied by Lieutenant-Colonel Stewart in a published notice inviting proposals for the removal of the upper part of Noonday Rock, to insure an average depth of forty-five feet at mean low water. As the terms require the completion of the operation within the year 1875, and all the conditions are well known, the early removal of this obstacle in the seaward approach to San Francisco Bay is not a matter of doubt.

Hydrography of San Francisco Bay.—At the opening of the fiscal year, work was resumed in San Francisco Bay by the hydrographic party in the schooner Marcy, under charge of Assistant Gershom Bradford. Soundings were made between the shoal north of Yerba Buena Island and

the Oakland Flats, and, compared with previous results, these give evidence of both deepening and widening of that channel.

South of Oakland Wharf, and near the mouth of San Antonio Creek, where close soundings were recorded, no very considerable change is apparent. The twelve feet and eighteen feet curves coincide nearly with those traced twenty years ago. Assistant Bradford notes that Blossom Rock at the lowest tides may have on it a depth of only about twenty-one feet, and that some of the vessels that resort to San Francisco as a port draw twenty-six feet of water.

In a previous report, mention was made of the wreck of the ship Flying Dragon as a danger in navigation. The party in the schooner Marcy carefully examined, by means of drags, the spot in which the obstruction had settled, but no part of the wreck remains there. Numerous observations were recorded on the currents of the bay. Those at the surface were determined by a pole reaching down about twelve feet, so that results might apply for vessels of average draught. In the subcurrent observations, the number of sets recorded were proportioned to the depth of water. Mr. Bradford used for results below the surface the connected cans first proposed by Prof. Henry Mitchell. Of three current-stations in each series, one was in the fair-way of the channel, and one on each side of it, but near the edge of the channel. About Southampton Shoal, the stations were increased in number, with a view to results that may aid in developing the causes of its formation. In regard to it, Assistant Bradford mentions as a significant fact "that the sand of which the shoal is chiefly composed was, at one of the stations, found to be underlaid by mud at the depth of seven feet." This was noticed on raising a screw-pile which he had used there as a tide-gauge.

For stations at the surface and below it, the currents have been plotted in diagrams, showing velocity and direction, and also the corresponding tidal curve at the nearest station. From these, current-tables were constructed in which the large flood and large ebb were separated from the small ones, the mean of the two differing, for practical uses, too much from either. In the course of the work south of Bird Rock a great difference was noticed in the slacks of ebb and flood.

Assistant Bradford and his aid, Mr. F. Westdahl, recorded upward of 6,000 observations for determining the direction and velocity of currents. In December, 1874, the party sounded out the space between Peninsula Point and Point Cavallo, and developed the character of the bottom from that line upwards abreast of Saucelito and into Richardson's Bay, as far as the transverse line of soundings showed a depth of seven feet. Opposite to Saucelito, the eighteen feet curve includes a space somewhat more than a hundred yards in width, and for that vicinity the chart shows some soundings in five fathoms. The general statistics of the hydrographic work are:

Miles run in sounding	481
Angles measured	5,237
Number of soundings	18,434

Through the winter and until March of the present year, Mr. Bradford continued the series of observations on currents. As the time approached for resuming hydrographic work near Humboldt Bay, the party was transferred from the schooner Marcy to the schooner Yukon, the former being no longer serviceable for work along the coast.

Tidal observations.—Under the immediate direction of Colonel Mendell the series of tidal and meteorological observations at Fort Point, Cal., have been kept up by the observer, Mr. E. Gray. As usual, the observer tabulates the high and low waters and the hourly ordinates as derived from the curve of tidal rise and fall.

Reconnaissance.—In order to adjust the preliminaries for a chain of large triangles to pass eastward from points near the Pacific coast, Assistant William Eimbeck took the field on the 20th of April at Mount Diablo. After several days passed there in expectation of determining the practicability of a line of sight to Mount Shasta, the party proceeded to Fairfield, and from thence to Vaca Station, which was reached on the 1st of May. The mountains in this locality being very rugged and densely covered with brush, many hardships were endured. In successive ascents from one to another of the points deemed favorable for seeing the distant stations which had been marked for recognition, the issue was not promising, but after seven days and passing several nights at different places on the highest part of the mountain, Mr. Eimbeck recognized the crest of the Sierra.

At the same point, however, the summit of Shasta was invisible. Proceeding eastward, the party traversed the country to Monticello and Knoxville. At Lakeport, arrangements were made for occupying Snow Mountain for reconnaissance purposes, and the southern summit was reached on the 14th of May. This being unfavorable, the party moved to the northern summit, and in the course of two days a position was found at which Mount Shasta could be seen. The station is 3,000 feet high and extremely difficult of access. In the middle of May, the party on the summit found the air so cold as to require a constant fire near the shelter-tent. After completing the preliminary observations at Vaca, Mr. Eimbeck left for Marysville Butte by way of Colusa. The summit of the South Butte was reached on the 24th of May, and the practicability of a line to Mount Shasta was quickly decided. Returning to Marysville on the 26th of May, Assistant Eimbeck plotted the points which had been determined by reconnaissance as intervisible, and studied for perfecting the scheme with additional points in the chain of triangles.

Early in June, Mr. Eimbeck made repeated examinations from the summit of Pilot Hill and also from points on Pine Hill. Other localities were examined in the course of an extended journey by way of Promontory Spur and through Auburn and Colfax to the summit of the Central Pacific Railroad, where all the members of the party rejoined Assistant Eimbeck in the middle of June. A few days after, the summit of Lola Mountain was occupied, and within a week a peak of Mount Shasta was recognized. From Mount Rose, that high summit not being visible, Mr. Eimbeck went to Castle Peak and spent a day in making observations from the summit of its eastern prong. His party was in that vicinity at the end of June, when the last field-report was dispatched by Assistant Eimbeck.

Dangerous rock off Cape Mendocino.—At intervals, in past years, many rocks have been determined in position in the vicinity of Cape Mendocino. On most of these, however, the water breaks in ordinary weather, and being thus commonly known, they are probably not reckoned as dangers by navigators who pass and repass the cape frequently. The usage of vessels along this part of the coast, in going inside of known dangers, has been repeatedly mentioned in the field-reports. Assistant Rodgers, while the topography of the adjacent coast was in progress, provided, as far as practicable, against resulting disasters by watching, in stormy weather, for breaks that had not shown under ordinary circumstances. Assistant Bradford, in charge of the hydrographic party, early in 1873 gave special attention to the development of unknown dangers that might exist between Blunt's Reef and the cape, and several spots at which the water broke were then approximately determined by the hydrographic aid, Mr. F. Westdahl. To his careful observation at that time, is mainly due the discovery, which was made in April last, of a dangerous sunken rock southwest three-fourths west by compass, and distant a mile and three-quarters from the light-house on Cape Mendocino. The rock has only six feet of water on it, is not more than three feet in diameter at the top, and is not marked by kelp. Soundings alongside gave nine and ten fathoms, and near-by, the water rapidly deepens to fifteen fathoms. In reference to this danger, the following remark is made in the report of Assistant Bradford: "The development of the rock settles any question in regard to the danger of this passage without a pilot, for it is evident that a stranger could only make moderately sure of safety by keeping close inside of Blunt's Reef, and the gain of barely one mile in the run, between Point Gorda and False Cape, would not compensate for the risk incurred in passing midway between Blunt's Reef and Cape Mendocino. Moreover, the water on a rock of such peculiar shape will break only under very exceptional conditions; and, though so near the surface, the danger rarely shows any sign of its existence."

Of the particular point of rock found and determined in position by Mr. Bradford, there was no previous knowledge, or even a hint, unless it be taken as the rock mentioned by Assistant Davidson in his Directory, as seen in 1857, *under the wheel of the steamship Commodore.* Such dangers are likely to baffle, in the search for them, all ordinary expedients. Pilots, of tried skill and experience, have repeatedly run their tug-boats through this passage without seeing the rock in question. While setting up signals on shore, in 1872, Assistant Bradford carefully inspected the reef from a station on high land, located many breaks, and afterward found the rocks which occasioned the breaks. At that time, he also brought into requisition a drag, about sixteen feet long, and reaching well below the surface of the water, and that was constantly in use while the party

worked near Cape Mendocino. It is evident that the existence of rocks so sharp as to elude detection when such means are applied, makes the passage inside of Blunt's Reef unsafe for navigation. The risk will be only in a degree lessened when all the hidden dangers are found and accurately marked on a chart showing their relative positions.

Hydrography between Point Gorda and Rocky Point, coast of California.—In the course of the present year, additional soundings, to develop the coast hydrography, have been made between these limits by Assistant Bradford, with a party, in the schooner Yukon. Early in April, he occupied some of the stations, at which signals had been previously erected, to include about fifty miles of coast-line. The work was continued throughout May and June, and was joined with the hydrography of 1872, completing the inshore soundings between Rocky Point and the limit, two miles below Cape Mendocino. As means additional to the facilities afforded by the schooner, a steam-tug was chartered, and was effectually used in prosecuting the inshore hydrography. A synopsis of the statistics of work is appended:

Miles run in sounding	766
Angles measured	6,313
Number of soundings	11,106

Thirty-one signals were erected, and eighteen positions were determined at intervals along the coast between Cape Fortunas and Rocky Point. The hydrography done this season, closing with the 30th of June, is represented on three sheets. Humboldt Bar was examined by Assistant Bradford on the 12th of April. He remarks in reference to it: "I found a great alteration in the direction of the channel, though the change must have occurred previous to May, 1872, for the same ranges are in use now as we often used for crossing the bar while sounding on Blunt's Reef off Cape Mendocino. The depth, however, is about two feet less at the present time. At favorable times this season, lines of soundings were run across the bar, showing that depth only had been affected, and not the direction of the channel, which is straight, of good width, and in the direction of the swell, so that, with a steady, fair wind, and moderately smooth sea, there is little difficulty in entering with a sailing-vessel, the ranges being known and visible. At mean low water, the average depth is nine to ten feet."

The coast hydrography was extended seaward to an average distance of rather more than four miles from the water-line, the work terminating generally at the depth of thirty fathoms. Where hidden rocks were suspected, the soundings were increased in number; and a drag was kept in constant use, while the hydrography was in progress, between Rocky Point and Pilot Rock. The approach to Trinidad Mr. Bradford found to be exceptionally free from dangers. The sunken rocks in that vicinity being quite near to the rocks in view are readily avoided. "The general character of the bottom is fine gray sand, looser and with black specks off the bar at Humboldt; and, receding from shore, the sand becoming gradually mixed with mud. In depths of thirty to thirty-five fathoms the bottom is wholly of mud, and that mud-line (well defined by soundings made in 1872), will, if sought for, be found of benefit to vessels when approaching the coast."

For the adjustment of soundings, made by the party in the schooner Yukon, the tides were observed at Red Bluff, near the entrance to Humboldt Bay, and at Trinidad. By a previous comparison of tidal results it was found that the difference in time was not appreciable between Cape Mendocino and Trinidad.

Coast topography north and south of Ten Mile River, Cal.—At the opening of the fiscal year, two plane-table sheets were projected to receive the details of topography yet unsurveyed between Shelton Cove and Point Cabrillo. For prosecuting the field-work, the party of Assistant A. F. Rodgers was dispatched from San Francisco on the 22d of July, 1874. Mr. E. F. Dickins, the aid, took up the coast topography at Abalone Point, and conducted the work southward, while Mr. Rodgers was engaged at San Francisco in computing the positions of several light-houses from observations recorded earlier in the season. When he joined his party, the plane-table survey had been advanced to a point about seventeen miles northward of Noyo River. Early in September, the working-camp was moved to Belobida Creek, from which station the sheet then in hand was conveniently finished, and work was commenced on the remaining sheet. Meanwhile, Assistant Rodgers examined the region, and selected a site on the beach at Ten Mile River, with a view of

measuring a base-line for verifying the triangulation which he had extended from the northward to join with that done in preceding seasons. A preliminary alignment was made, but the measurement was deferred until the plane-table operations had advanced to the vicinity.

Much difficulty was experienced in crossing Ten Mile River. Even at low tide, the party found at the beach a heavy swell that sent runners several feet high up the river. Assistant Rodgers and Mr. Dickins crossed and recrossed at the ford on the 29th of September, with saddle-horses, and, by carefully leading the way, the teams with the baggage of the camp safely passed the stream and reached a deserted cabin five miles to the southward.

The final plane-table sheet of the coast work between Trinidad Head and Point Arena includes the details between Ten Mile River at its north limit, and Pudding Creek at the south, where the work was joined with that of Assistant Sengteller. In the middle of October, topographical work was suspended, the weather then being most favorable for determining the length of the line selected at Ten Mile River entrance. The result of measurement (1,516.29 meters) was satisfactory as a check on the detailed work, which now represents seventy-seven miles of coast north and south between the bases on Navarra Ridge and Shelter Cove.

While Mr. Rodgers extended his triangulation south of Ten Mile River, the topographical work was advanced by Mr. Dickins, and was joined on the 1st of December with a survey made previously by Assistant Sengteller. The statistics of the field-work are:

Signals erected	9
Stations occupied	9
Angles measured	34
Number of observations	1,569
Coast-line surveyed, miles	20
Streams, miles	15
Roads, miles	23
Area of topography, square miles	28

The following remarks were taken from the field-report of Assistant Rodgers:

"This season was exceptional in the early commencement of settled rain; from October 18 to November 24, fourteen rainy days interfered materially with the progress of our work. Early in November a sudden freshet in Ten Mile River carried away fences, horses, cattle, and hogs, and an Indian attempting to cross on horseback lost his life, both man and horse being swept into the breakers and drowned.

"Most of the coast-streams here close for a period near the end of the dry season of each year, the sand forming in a bar at each outlet. As a result, water accumulates on the valley-lands, until a heavy rain-storm, by sudden increase of pressure, breaks the barrier, when the stream again assumes its normal character. This is the case at Little River, near Trinidad; Mad River, north of Humboldt Bay; Bear River, three miles north of Cape Mendocino; Mattole River, twelve miles south of the cape; Ussal Creek, thirty miles south of Shelter Cove; Ten Mile River; Gualala River, fourteen miles south of Point Arena; at Russian River (closed about five weeks in each year); Salmon Creek, north of Bodega Head; and at Pudding Creek, which empties at the coast one mile north of the mouth of Noyo River."

This closure of the rivers causes serious inconvenience, the ordinary fords being at such times either useless or dangerous. While his work was advancing in the vicinity of Pudding Creek, early in November, 1874, Assistant Rodgers, in the course of a few hours, with four men, started a trench across the barrier of that stream, sufficient to admit the flow of some water toward the mouth. While the water was shallow, an hour was spent by the party in riding on horses through the trench, and thus loosening the material of the barrier; and at noon next day, farm-wagons crossed in only two feet of water at the ford, which for a long period had been impracticable. "On the 1st of November, the lower reach of this creek presented the appearance of a lake, close to the ocean-beach, but with no outlet; and during six weeks, the gradual accumulation of water had covered all adjacent low ground, and deepened the usual ford to about ten feet."

After observing at Sand Hill Station for azimuth, Mr. Rodgers moved to the Noyo, and there

discharged his party, and reached San Francisco on the 8th of December. Office-work, including the computations and inking of details on the plane-table sheets, was completed in the course of the winter.

On the 10th of March, Assistant Rodgers took the temporary direction of details in the office at San Francisco, and provided the requisites in data and projections for the intended field-work and hydrography of the present year. Subassistant G. Farquhar, at the same time, joined the office, and made tracings of previous work, which was to be joined by the operations of the season in hydrography. Early in April, Mr. Rodgers, at my request, ascended Mount Shasta for special reconnaissance, mention of which will be made before closing notices of work in this section.

Redding's Rock.—When my report of last year closed, Lieutenant-Commander Taylor, and, in co-operation, Assistant A. W. Chase, were awaiting a favorable opportunity for landing on this rock, to erect a signal for use in determining its exact position. The steamer Hassler, on the 19th of September, 1874, was anchored off the upper gold-bluffs, nearly opposite, at the close of a severe northwester; but the continued heavy sea and dense fog prevented all attempts to land until the 21st, when a boat from the steamer was safely moored at the rock. It was found to be an immense mass of quartz, gray and white, containing mineral of some kind, the summit of the rock being merely a narrow ridge. Holes were drilled to admit a signal-pole twenty-seven feet in height, and its requisite support. While the hands of the topographical party were so employed, Lieutenant-Commander Taylor and Mr. Chase applied the plumb-line at the western side of the rock, and found that it stood ninety-four feet out of water.

Redding's Rock is about five miles off the coast of California, and about midway between Rocky Point and Klamath River. The bottom all around is rocky, and the average depth is twenty fathoms.

Fogs prevailed during all the time allotted for operations; and, although the signal was set and secured, none of the signals on shore were visible from the rock during the stay of the party. Angular measurements were of necessity deferred, as the steamer could not be detained at that time to admit of determining the exact position of the rock. Assistant Chase returned to his working-ground on the mainland, and completed the coast-triangulation between Klamath River and Rocky Point, connecting at Big Lagoon with the survey which had been extended northward by Assistant Rodgers. Several attempts to land on Sister Rock were prevented by stormy weather; and that station, like Redding's Rock, remains to be occupied as the apex of a series of triangles, the bases of which connect with each other from point to point along the coast. The following are statistics of the triangulation in this quarter:

Signals erected	12
Stations occupied	11
Angles measured	42
Number of observations	768

After his return to Crescent City, Mr. Chase made, for the uses of the Light-House Board, and furnished to Lieutenant-Colonel Williamson, a tracing from the plane-table sheet of the survey of Point Saint George. The tracing shows the arc of visibility from a proposed light-house location which is 156 feet above the water-level, and was marked also with the height of each of the prominent rocks in that vicinity. Subsequently, Mr. Chase proceeded to San Francisco, and there, by the middle of January, completed the computations resulting from his field-work.

Inshore hydrography from False Klamath, Cal., to Mack's Arch, Oreg.—Lieut. Commander H. C. Taylor, U. S. N., assistant in the Coast Survey, with the steamer Hassler, left San Francisco on the 10th of June, 1874. A few days after, his party took up and prosecuted until the end of September the inshore hydrography of the Pacific coast above and below the boundary-line between California and Oregon. The stretch of coast-approaches, developed by soundings in the course of the season, is about fifty-five miles, and, seaward, the lines were extended to an average distance of six nautical miles. One of the sheets shows, in connection with inshore soundings, the depths in Lake Earl and Lake Tollawa, and another, the channel at Smith's River entrance.

In the reach included within the working limits of the party in the Hassler, four dangers to navigation were discovered, and, as customary, reported immediately. On a rock found in the

anchorage of Crescent City Harbor, Lieutenant-Commander Taylor maintained a mark pending the arrangements for placing a buoy. Of these dangers, two of which were mentioned in my last report, one was found off the False Klamath, and one in the anchorage of Chetko Cove. Abreast of the California and Oregon State line, the inshore soundings developed the character of a danger well off shore. Information concerning these rocks, and other matters of interest in navigation, was communicated from the surveying-steamer directly to captains of steamers and sailing-vessels, as they passed to and fro. In this vicinity, Lieutenant-Commander Taylor met earnest inquiries in regard to anchorages, the best being sought as the terminus of a wagon-road 120 miles long, to lead from Jacksonville to the coast.

Crescent City Reef having been thoroughly sounded, a tracing of the chart was furnished at the request of an agent who was searching, with a party of divers, for property lost by the wreck of a vessel some years ago on one of the rocks of that reef. As stated under the last head, the operations of the land-party, when working near Redding's Rock, were assisted by the temporary use of the Hassler, and the personal co operation of Lieutenant-Commander Taylor. In the time given to aid of the work in charge of Assistant Chase, soundings were made in the vicinity of the rock. The depth immediately around it is eighteen fathoms, but the water deepens to twenty-three fathoms midway between Redding's Rock and the main, and from that depth the water shoals gradually to the beach.

On a review of the hydrographic work, Lieutenant-Commander Taylor thus observes, in his report, at the end of the season: "Beginning at the south, the water deepens off shore about five fathoms per mile, and this appears to be unaffected by the outlying rocks which, in this section, fringe the coast almost everywhere. With the exception of Crescent City Reef, where the bottom is broken and irregular, this average deepening per mile off shore continues as we proceed northward to Chetko Cove. Above that, a much more rapid deepening becomes well marked off Barnacle Rock, and reaches a maximum (as far as yet known) abreast of Mack's Arch, where fourteen fathoms per mile off shore is the average increase of depth. We there find seventy fathoms, but off the False Klamath only thirty fathoms at the same distance from the beach."

On the important subject of anchorages, it is remarked by the same officer: "Increasing commerce makes only more distinct the lack of shelter on this coast. At an early day, doubtless, measures and means will be sought for making artificial improvement. Hence, it seems proper to put on record such reliable information as can be had in advance in regard to the few existing anchorages. One of these, which I have named Mack's Shelter, may be said to have been hitherto unknown. Some swell rolls in, but not much; the place is undoubtedly a good northwest lee; and, judging from the small amount of wash apparent on the cliff, and from the undisturbed kelp in the upper part of the shelter, I conclude that there the violence of wind and sea in the southeasters of winter is considerably reduced, and that a tolerable southeast lee can be here obtained."

The following remarks bear on the capability of this anchorage for artificial improvement: "A breakwater, extending from the beach to the reef, or only part of the way, would give excellent results. If built across in five fathoms, it would afford good accommodation for schooners, small steamers, and the coasting-trade; if in eight fathoms, it would give anchorage to all classes of vessels, and ample room for all probable needs; while, if built in ten fathoms, the result would be a most admirable and capacious harbor. There is no village, and the nearest settler lives some miles distant; but the problem of a harbor on this stretch of coast will be solved in the interest, not of the scanty population of the vicinity, but in that of the busy and rapidly-increasing population of the valleys in the interior of Southern Oregon and Northern California."

The hydrographic sheets sent to the office by Lieutenant-Commander Taylor were accompanied by sailing-directions for entering Mack's Shelter, for the channel of Smith's River, and also for navigating at Crescent City Reef. The statistics of the work are:

Miles run in sounding	800
Angles measured	2,980
Number of soundings	8,050

As chief of the hydrographic party, Lieutenant-Commander Taylor, in his official report,

specially mentions the services of the executive officer of the Hassler, Lieut. George Talcott, U. S. N., to whose suggestions and skill in details is attributed much of the success in operations. The cheerful zeal and ability of Lieut. Frank Courtis, U. S. N., Lieut. Richardson Clover, U. S. N., Lieut. J. D. Adams, U. S. N., and Lieut. G. W. Tyler, U. S. N., in furthering the hydrographic work, are commended in the same report.

Mount Shasta, Cal.—To provide in advance for such uses as might be made of Mount Shasta in the determination of geographical points, Assistant A. F. Rodgers, at my request, visited the region, ascended the mountain on the 28th of April, and reached the top after a steady walk of twelve and a half hours over and through snow that, in occasionally giving way, allowed himself and attendants to sink waist-deep. After remaining an hour on the summit, Mr. Rodgers moved down to the hot springs, a patch of about a hundred square yards, and several hundred feet below the highest point of the mountain. Near the springs, which are alkaline, and unfit for drinking or for cooking purposes, frequent jets of steam were seen to issue from fissures and rise eight or ten feet in air, the temperature at the time being 2° below the freezing-point. In regard to surface-features, he thus reports: "Shasta summit is a triple ledge of shattered lava, the fragments being of all sizes and lying at all angles, many of them ready to roll off down the mountain under little exertion of force. In a range of about 150 feet at the summit, the south point of ledge is the highest, the north point being twenty feet lower." Several of the large blocks of lava interfere with lines of sight to the southward, and involve, additional to the cost of a signal, some expense in securing a large arc of visibility from stations toward the southward. Assistant Rodgers, nevertheless, deems it practicable to occupy the summit as a station, and, for future reference, he has filed with his report notes and remarks that will have special value if it should be found expedient hereafter to erect a signal on Mount Shasta. The geological and botanical characteristics of the mountain were observed and recorded by Mr. John Muir, who accompanied Mr. Rodgers in the ascent, and to whose intelligence, physical endurance, and experience as a mountaineer, the field-report ascribes the success of the undertaking. Mr. Muir's description of the storm, which constrained him to pass the night with a single attendant on the summit of Shasta, is made specially interesting by his careful record of all the changes attendant upon storm-formations at an elevation of about 14,000 feet. Common as they doubtless are at such heights, descriptions are even more rare than occasions that have constrained some few observers in the past to witness the terrible phenomena.

SECTION XI.

COAST OF OREGON AND OF WASHINGTON TERRITORY, INCLUDING THE INTERIOR BAYS, PORTS, AND RIVERS.—(SKETCHES NOS. 19 AND 20.)

Hydrography between Chetko Cove and Mack's Arch.—Inshore soundings along this part of the coast of Oregon were prosecuted in continuation of hydrographic operations in Section X by the party of Lieutenant-Commander Taylor, U. S. N., assistant in the Coast Survey, in the steamer Hassler. As the work was of necessity mentioned under that section, the extension of the hydrography somewhat above the north boundary of California was not regarded as calling for a subdivision of the abstract, a subdivision in respect of the statistics of work not being practicable.

Coast-triangulation and topography near Nehalem River, Oreg.—Early in July, 1874, Subassistant J. J. Gilbert completed the triangulation of the coast between Columbia River entrance and Tillamook Head. The topography was then taken up and was prosecuted until the end of October. Four plane-table sheets containing the results have since been inked, and are on file in the office. These represent twenty-five miles of the coast-line south of Point Adams, and the adjacent features of topography, amongst which are Tillamook Head, and below it the vicinity of the mouth of Elk Creek. Mr. Gilbert remained in the field until the 6th of November, and occupied the last week of the season in measuring horizontal angles for connecting the survey of Shoalwater Bay with the triangulation of Columbia River. He then stored the instruments and camp-equipage at Astoria for the winter, and took up office-work and computations.

At the end of April, 1875, the camp-fixtures of the party were sent by sea to Tillamook Bay, and in the course of the following fortnight field-work was resumed at the mouth of Nehalem

River. As weather would permit, lines were opened for extending the coast-triangulation, and the requisite signals were set up. The wet season, however, continued, and deferred observations with the theodolite. Of forty-one days after commencing work at the mouth of the Nehalem, nineteen days were rainy. Subassistant Gilbert is yet in the field, and engaged in completing the coast-triangulation between Tillamook Head and Nehalem River. His party will remain in that region as late as the weather will permit, and at the approach of winter will discontinue field-operations as heretofore.

The following is a synopsis of the statistics of work done within the fiscal year:

Signals erected	36
Stations occupied	25
Angles measured	152
Number of observations	4,518
Shore-line surveyed	50
Creeks, miles	5½
Roads and trails, miles	60½
Area of topography, square miles	42

Mr. F. Westdahl is now attached to this party as aid, and full provision has been made for the prosecution of such hydrography as may be found practicable for a small vessel, within the limits of the plane-table survey.

Survey of Columbia River.—In May, 1874, projections were made for continuing the detailed survey of the Columbia upward from the limits which had been reached in the preceding year. Assistant Cleveland Rockwell was soon after established in camp at Oak Point, but in the course of a week a case of small-pox occurred amongst the hands. The man was properly cared for, and although the entire party had been exposed to the disease, work was continued as usual, and no other person was affected by the pestilence. Early in July, Mr. Rockwell permitted the hand to return to camp and resume duty.

The character of ground traversed by the party in the operations of this fiscal year has been mentioned in previous reports. The north, or Washington Territory side of the river, is abrupt, precipices of columnar basaltic rock on that shore having deep water at their bases. These walls are several hundred feet high and surmounted by a dense covering of fir timber and an abundant undergrowth. The opposite side of the river is a broad expanse of marsh lands, liable to be submerged in June by freshets, and in winter by high tides. Numerous sloughs traverse the ground, and some of the channels are deep enough for navigation. Of these low lands, the parts nearest to the river are in all cases a little higher than ground a hundred yards back, and are covered by a heavy growth, mostly cottonwood, with some ash and oak. As no use is made at present of the low lands, the survey includes the basin on the south side of the Columbia, and part of the high land which bounds it. The season was more than usually unfavorable. In August, field-progress was hindered by ten rainy days in succession. Two plane-table sheets were completed, and on a third the detailed survey was advanced as far as Smith's Island. As the plane-table work required, Mr. Rockwell established points from time to time by triangulation. The statistics are:

Shore-line surveyed, miles	43
Creeks and marsh, miles	101
Area, square miles	35

Assistant Rockwell was aided in the field by Mr. G. H. Wilson. The party was disbanded at Oak Point in the middle of October, and was subsequently engaged in work which has been noticed under the head of Section X.

Tidal observations.—At Astoria, the excellent series of tidal and meteorological observations have been continued by Mr. L. Wilson, under the direction of Col. G. H. Mendell, United States Engineers. The hourly ordinates and high and low waters are tabulated by the observer, and filed with the records which are taken from the self-registering gauge.

Detailed survey of Duwamish Bay, W. T.—Assistant J. S. Lawson was in the field with his party, on the shores of Duwamish Bay, when my last annual report closed. The triangulation was prosecuted until November, 1874, when the party in the brig Fauntleroy was disbanded

for the winter. Mr. Lawson then took up and completed his computations and sent to the office the records of the work in duplicate. Six plane-table sheets of the previous season were also inked, and are now in the archives. In this service, Mr. F. A. Lawson aided until February of the present year, when he was temporarily assigned to the party of Assistant Chase.

Late in March, preparation was made for resuming field-work on the eastern side of Duwamish Bay, but, owing to prevalent bad weather, operations were deferred until the middle of April. The season proved to be more than usually unfavorable. Of sixty-five working-days, the daily journal marked thirty-five as rainy and unfit for the use of the plane-table. At such intervals, however, the party employed the level-instrument, and thus advanced the detailed survey. The topography includes the head of Lake Union, the surface of which Assistant Lawson found to be about twelve feet above the high-water line of Duwamish Bay. On the plane-table sheet, the delta is also shown, and two miles of the course of Duwamish River above the delta. A detailed survey was made of the town of Seattle and of the roads adjacent.

Mr. T. P. Woodward, after his return from service abroad, as an observer of the transit of Venus in December, 1874, was assigned to duty in this section, and joined Assistant Lawson early in April. At the end of the fiscal year he was transferred to the party of Assistant Chase, and was replaced by Mr. F. A. Lawson. The following are statistics of the work at Duwamish Bay:

Shore-line surveyed, miles	20
Roads, etc., miles	25
Details, area in square miles	4

For service in prosecuting the hydrography, the steam-tender Lively is now under the charge of Assistant Lawson. Soundings are in progress in Duwamish Bay.

Tidal observations.—At Port Townshend, owing to the roughness of the place about the tidal station, the pendulum-clock, attached to the only tide-gauge available when the station was established, occasionally stopped when the winds were strong. To meet this inconvenience, a gauge of the new form, and provided with a time-keeper, which is operated by a balance-wheel, will soon be substituted for the old apparatus. The observer, Mr. L. Nessel, conducts the operations at this station under the direction of Colonel Mendell, of the Corps of United States Engineers.

SECTION XII.

COAST OF ALASKA TERRITORY.—(SKETCH No. 21.)

Coast of Alaska.—When my report of last year was closed, Acting Assistant W. H. Dall had not returned from the coast of Alaska. The schooner Yukon, with himself and his party, arrived at San Francisco on the 12th of October, 1874.

On the 3d of May preceding, Mr. Dall took up the coast reconnaissance at Sitka, and from thence in passing up the coast recorded current and temperature observations and plotted soundings. Vertical angles were measured to determine the heights of mountains in that region that serve as landmarks at sea. Observations for time, azimuth, and latitude were made at Lituya Entrance, and the position given on most charts found to be erroneous. The chart of the inner bay, by La Perouse, was tested, and proved to be generally accurate. Here the party on the Yukon had much difficulty in preventing the persistent attempts of the natives to board the vessel, but fortunately they were kept off without bloodshed. It is added in the report that these natives distil their own rum, and are well supplied with the best kinds of fire arms. Before leaving the place, observations were made for correcting the positions heretofore assigned to Mount Fairweather and Mount Crillon. It is recorded that except at slack water the sea breaks quite across the entrance to Lituya Bay, even in calm weather.

A few days following the 20th of May were occupied in hydrographic work at Dry Bay, in reaching which the Yukon passed the seaward face of the Grand Plateau Glacier of La Perouse. Mr. Dall procured data for a corrected sketch of the bay, and for a general chart of the coast southward as far as Lituya Entrance. Of the region inland, he says: "The scenery is grand; the mountains, reaching 16,000 feet above the sea, are bedded in forest lowlands, and are scored by enormous glaciers."

At Port Mulgrave, Mr. Dall made a careful survey, the existing charts being very erroneous. Latitude, time, and azimuth were determined, and a good series of observations were recorded for ascertaining the heights of Mount Saint Elias, Mount Fairweather, and other peaks in view. Here the party in the Yukon found evidences of the murder by natives of a boat's crew supposed in 1870 to have been lost at sea, but which in that year went ashore from a whaling-vessel commanded by Captain Herendeen, the present sailing-master of the Yukon. In regard to a small trading-vessel from Sitka, the arrival of the surveying-party was timely, in averting rough usage by the savages.

Late in May, soundings were tried on the so called Pamplona Bank, but no bottom was found with 575 fathoms of line. Elsewhere on this bank, to which attention has been drawn by the report that a rock with kelp existed, it is believed that the depth may be no more than 75 fathoms; but no search has yet developed the existence of a danger to navigation.

At the end of May, Mr. Dall and his aid, Mr. Marcus Baker, recorded observations at Port Etches for latitude, time, and azimuth. The vessel then passed on to Middleton Island, where similar observations were made, and a sketch of the island for transfer to the general chart. Kadiak was reached on the 4th of June. After rating the chronometers of the Yukon and observing for azimuth and the magnetic elements, Mr. Dall sailed for Chirikoff Island. Soundings were made of the space used as anchorage, and the position of the place was determined by astronomical observations. On the 12th of June, the vessel anchored near the Semidi Islands. Azimuth and latitude were determined, and a sketch was made for the general chart. Sailing next day, a safe anchorage was sought for in Chiquik Bay. Here the vessel was detained ten days by bad weather, but, at favorable intervals, latitude, time, and azimuth were obtained, the anchorage was sounded, and also the northwest bight of the bay. Mr. Dall next proceeded to the vicinity of some rocks that exist about sixty miles west of the Semidi group. Observations were recorded for position, which, however, must be regarded as merely approximate, there being no landing-place at the rocks, nor anchorage for the schooner, the least depth found near the rocks being 45 fathoms. On the 25th of June, a spot was selected on one of the Chiachi Islands, and observations were recorded for latitude, time, and azimuth. Proceeding to the Shumagins, the Yukon was anchored on the 1st of July in Northwest Harbor, Little Koniushi Island. In that vicinity, Mr. Dall completed the triangulation of the harbor. Latitude, azimuth, and time were determined, and the survey of the group was extended by the tracing of shore-line and the record of soundings.

Several days were passed in the vicinity of the Sannakh Reefs, where numerous observations were made for determining in position and extent that danger to navigation.

The Yukon reached Unalashka on the 13th of July. Currents were observed constantly when the vessel was not in port. After due preparation at the anchorage, the party left for Saint Paul Island, of the Pribyloff group, and there arrived on the 22d. A sketch of the island was made, and observations were recorded for azimuth, time, and latitude. The position of the island, as given on the existing charts, was found to be six miles too far to the eastward, and the form as represented on them is also erroneous.

At Nunivak Island a reconnaissance was made of the anchorge and determinations of latitude, time, and azimuth. This island is much in error as represented on all previous charts. Leaving on the 2d of August, the Yukon was next anchored under Hagmeister Island, between Cape Constantine and Cape Newenham. Observations were made for geographical position, but the extraordinary mirage which prevailed prevented any trustworthy triangulation on the neighboring islands or adjacent mainland. Hence, sailing for Port Möller, a reconnaissance was made of that harbor, proving that it has been heretofore inadequately represented on charts. On the 16th of August, after a period of good weather, the Yukon steered for Saint George, but by heavy seas and winds was unable to land until the 22d, when series of observations were recorded for time and latitude. The position of that island is reported by Mr. Dall as being about thirteen miles in error, and that in form it differs greatly from the view of it given on charts. As bad weather continued, Mr. Dall returned to Unalashka, and there at favorable intervals extended the survey of Captain's Bay, which work had been begun by a party under his charge in 1871. The shore-line of the west side of the bay was traced in September, and determinations were made of the magnetic declination, dip, and intensity. These indicate that the declination is decreasing.

Winter set in early at Unalashka. A heavy fall of snow on the uplands, and constant rain, made it unadvisable to undertake further operations. On the 29th of September, the Yukon sailed for San Francisco, and there arrived after a stormy passage of thirteen days.

The following is a synopsis of statistics from the final report of Mr. Dall:

Latitude-observations at twenty-one stations	864
Time-observations at thirty-one stations	2,099
Azimuth-observations at sixteen stations	680
Magnetic-observations at fifteen stations	884
Horizontal and vertical angles	728
Number of soundings plotted	1,259

Amongst interesting results derived from the records of observations by Mr. Dall is that which proves the height of Mount Saint Elias to have been heretofore underestimated. D'Agelet, of the La Perouse expedition, assigns an elevation of only 12,672 feet; and amongst several other authorities that vary from each other the greatest elevation hitherto stated is 17,855 feet. Mr. Dall's observations, made with care and under circumstances favorable for accuracy, have been carefully tested in the Computing Division of the Office. The result is for Mount Saint Elias an elevation of upward of 19,000 feet. As proved from the same series of observations, Mount Fairweather and Mount Crillon have each an elevation exceeding 15,000 feet. Mr. Dall's observations are confirmatory of the position marked by the eminent navigator, Captain Cook, for Mount Saint Elias; and also of the positions assigned by the La Perouse records for Crillon and Fairweather, both of which have been erroneously marked on some subsequent charts. In Appendix No. 10 will be found an interesting paper by Mr. Dall on the determination of heights, including that of Mount Saint Elias on the coast of Alaska.

When in command of the United States ship Saranac, Capt. Thomas S. Phelps, U. S. N., formerly an officer on the Coast Survey service, and of large experience in hydrographic operations, had frequent occasion to traverse the interior waters of the southeast coast of Alaska. His constant interest in such details prompted a communication in October last, which was gratefully accepted as containing suggestions in regard to the relative importance of the channels in that quarter, and which will have special value when means are available for giving effect to the suggested plan of work.

COAST SURVEY OFFICE.

The charge of the Coast Survey Office has remained with Assistant J. E. Hilgard. To his long experience, eminent ability, and thorough comprehension of the requirements of the work is due the effective co-operation of the office-operations with those of the field.

In executive details, Assistant Hilgard had the aid of Assistant F. W. Dorr, until increasing ill health made it desirable that he should be transferred to field-service in December last, since which time the same duties have been performed by Assistant Edward Goodfellow.

Computing Division.—Assistant Charles A. Schott has continued in charge of this important division, and has kept it up to the high standard of exactness and efficiency maintained by him during many years, this abstract being based upon his twentieth annual report. The computations, according to their character, are distributed in general among the computers, as follows: Assistant T. W. Werner, though in very feeble health, has computed the current simple triangulations. Dr. G. Rumpf attends to the secondary triangulations, their adjustment and revision, furnishes all needful data for field-parties, and, where opportunity offers, attends to the bringing up of the older secondary triangulations. Mr. J. Main takes charge of the revision of the astronomical latitudes, longitudes, and azimuths, also of magnetic observations, and furnishes mean places of stars for observing-parties. Mr. E. H. Courtenay has charge of least square adjustment of primary and secondary triangulations, of measures of vertical angles, and miscellaneous geodetic work. Mr. M. H. Doolittle attends to the least square adjustment of primary and secondary triangulations, spirit-levelings, and miscellaneous geodetic work. Mr. H. H. Gerdes attends to the clerical duty of the division, supplies copies of records to field-parties, and inserts geographical positions in registers.

During the year, the following temporary computers were engaged:

Prof. R. Keith, on telegraphic longitude-work, for three and a half months; Mr. J. H. Lane, temporarily transferred from the Weights and Measures Department; Mr. F. Hudson, on reductions of latitudes and azimuth: Dr. C. Powalky, on astronomical latitudes; Mr. C. Ferguson, on computations of triangulation and levelings; Mr. J. B. Baylor and Mr. H. Caperton were employed a few days upon miscellaneous computations. Assistant Charles A. Schott personally examines and reports upon the work done under his charge, attends to the office-correspondence referred to him, and to such special discussions and computations as his time allows. He made the usual magnetic-observations in June last. The following reports submitted by him deserve special mention: Discussion of the magnetic-observations, both absolute and differential, made at Key West, Fla., between 1860 and 1866; and the computation and discussion of the three measures of the Atlanta base-line of 1872 and 1873. Under his direction, the factors for the computation of geodetic latitudes, longitudes, and azimuths have been extended from latitude 50° to latitude 65°. With the addition of the similar table of factors from latitude 23° to latitude 50°, already published, and a preface prepared by the assistant in charge, this appears in Appendix No. 19.

Tidal Division.—The inspection of the tidal and meteorological observations received at the office, the correspondence with the observers and others relating to tides, the furnishing of tidal data when wanted, the supervision of the construction and repair of tide-gauges and of the computations relating to tides have been kept by R. S. Avery, who has been assisted in the computations by A. Gottheil, Mr. J. Downes, Mr. L. P. Shidy, and Miss M. Thomas. A considerable amount of information respecting tides has been furnished for office-use, for observers and field-parties, and also for engineers and others not connected with the survey. To do this, the ordinary reductions of all the observations received are made as soon as practicable, and the results tabulated, so that they can be furnished for charts or other uses on short notice.

A particular account of what has been done at each permanent tidal station has been given in the general statement of progress in the section in which it is situated.

The predictions of tides for 1876, for both eastern and western coasts, are nearly completed, and will soon be published. For some of the places, these have been improved by using the results of new discussions based on longer series of observations, and such discussions form an important part of the labors of the tidal division.

Hydrographic Division.—Capt. K. R. Breese, U. S. N., served as hydrographic inspector from December 27, 1874, to June 3, 1875, when he was relieved by Commander E. P. Lull, U. S. N. Lieut. Henry E. Nichols and Acting Master Robert Platt, both of the Navy, are on duty in the office.

Mr. E. Willenbucher has been employed as principal hydrographic draughtsman; Messrs. W. C. Willenbucher and J. Sprandel as assistants. Their work includes the inspection and verification of hydrographic records and sheets, the plotting and drawing of sheets from the original note-books, the preparation of projections for the hydrographic parties, and various miscellaneous tracings and drawings.

The hydrographic inspector acts as the immediate assistant of the Superintendent in directing and inspecting the construction, repairs, outfit, and preservation of the vessels of the Coast Survey.

Drawing Division.—To this division is intrusted the preparation of all projections for field-work, the consideration of projects for charts, the reductions of the original topographic and hydrographic sheets, and the arrangement of the reduced drawings for the engraver or lithographer. The immediate direction of the details is in charge of Mr. W. T. Bright, whose experience and assiduity are constantly called into service.

The information furnished from the office in reply to special calls, and consisting principally of tracings from original sheets, is given in Appendix No. 3.

The charts completed or in progress, arranged in geographical order, are given in Appendix No. 4.

Of the persons employed, Mr. A. Lindenkohl has been, as heretofore, engaged upon the more elaborate hydrographic reductions as well as upon the small scale of offshore charts. Mr. H. Lindenkohl, upon fine topographical reductions for harbor-charts and photolithographic maps and sketches. Mr. L. Karcher, principally in making the numerous projections called for by the

field-parties. Mr. F. Fairfax was engaged upon hydrographic drawings and tracings until July 1st, when he resigned. Mr. P. Erichson has made diagrams, miscellaneous drawings, and tracings. M. C. H. Meuth traced for photographing to the publication-scale of $\frac{1}{80000}$ all the plane-table sheets turned in during the past year of portions of the coast of Maine, and lettered those of the Atlantic, Gulf, and Pacific Coast received during the same period. Mr. C. Junken returned from field-duty and was assigned to the division in May, since which time he has made projections for field-parties, plotted hydrographic work, and supplied the aids to navigation to most of the charts issued since that date. Mr. M. Angles has made tracings, corrected published charts, and done other miscellaneous work. Mr. W. Fairfax and Mr. Hugo Eicholtz made tracings, corrected charts, and colored buoys and light-houses thereon. Mr. W. Fairfax resigned July 1st. Mr. Arthur Schott had charge of the library, and performed occasional clerical work for the division.

In addition to the work done as given in Appendix No. 3, the following comprises a small portion classed as miscellaneous:

Projects for new charts prepared	15
Tracings made on special calls	58
Projections made for field map and charts	73
Diagrams made	12
Projections made on copper for engraving charts	8
Topographical sheets traced for reduction by photography	7

Engraving Division.—The charge of this division has been continued with Assistant E. Hergesheimer. Its labors are shown in detail in the table (Appendix No. 5) of plates begun, in progress, and completed during the period indicated.

The distribution of work among the persons employed has been as follows: Messrs. J. Enthoffer, S. Siebert, H. C. Evans, A. Sengteller, W. A. Thompson, A. M. Maedel, and R. F. Bartle have been classified as topographical engravers; Messrs. E. A. Maedel, F. Courtenay, and A. Peterson as letter engravers; Messrs. H. M. Knight, J. G. Thompson, J. J. Young, E. H. Sipe, W. H. Davis, and W. H. Knight as miscellaneous engravers.

The pantograph for the transfer and reduction of outlines has been used by Mr. E. Molkow. Mr. L. C. Kerr has performed the clerical duties of the division.

Careful study has been given by Mr. Hergesheimer to the introduction of such improvements in design and execution as have seemed best adapted to advance the artistic character of the work in his division.

Electrotype and Photographic Division.—Dr. A. Zumbrock has remained in charge, assisted by Mr. Frank Over. His report, which will be found in Appendix No. 6, gives an interesting account of the improvements in methods and apparatus introduced by him in the course of the year.

A very successful application of the recently-discovered process of steel-facing copper plates has been made to the finely-engraved plates of the centennial certificate of stock for the Treasury Department.

Since October 1, 1874, there have been prepared twenty-four altos, and thirty-six bassos or printing-plates. Nine positives, twenty negatives, and fifty-four prints have been made for the use of the draughtsmen and engravers.

Division of Charts and Instruments.—The work of this division, which includes, besides the safe-keeping of the archives and instruments, the printing of maps and the distribution of charts and reports, the management of the instrument-shop and the carpenter-shop, has been directed by Mr. John T. Hoover, who has also kept the accounts of the office and made disbursements for the assistant in charge.

The duty of registering and filing for convenient reference the original maps and charts, and records of observations made by the field-parties, and of keeping an account of the same as they are used temporarily in the office, was performed by Mr. G. A. Stewart.

A period of ten years having elapsed since the publication of lists of the original topographic and hydrographic sheets, forming part of the archives of the survey, arranged in geographical order

from the date of their earliest registry, it has been deemed advisable to republish these lists (Appendices Nos. 7 and 8) with the addition of the original sheets which have been deposited in the archives since the year 1865.

During the year, the copper-plate printer in the office, Mr. Frank Moore, has rendered 15,319 copies of charts ready for issue.

Mr. H. Nissen has prepared the backed drawing-paper for field and office work, and also the miscellaneous duties pertaining to the folding-room.

The map-room has remained under the care of Mr. Thomas McDonnell. An aggregate of 14,000 copies of charts has been issued during the year, and 532 copies of the annual reports of various years have been distributed.

The work in the instrument-shop was done, under the supervision of Mr. John Clark, by John Foller, W. Jacobi, G. N. Saegmuller, W. Suess, and E. Eshleman.

The wood-work of instruments, their packing for transportation, and all carpentry work required in and about the office was done by Mr. A. Yeatman, assisted by F. E. Lackey and James Hess.

Since the resignation of Mr. V. E. King, in May last, the duties of clerk in the office of the assistant-in-charge has been satisfactorily performed by Mr. Charles H. Fitch. In the office of the disbursing-agent, Samuel Hein, esq., Mr. R. L. Hawkins has remained as principal book-keeper and accountant. Messrs. W. A. Herbert and W. I. Flenner have performed the clerical duties.

In the distribution of means available for field and office work many details are involved, the adjustment of which, by the foresight and large experience of the disbursing-agent, Samuel Hein, esq., has invariably secured promptness in the operations. Under my immediate direction, Assistant W. W. Cooper has also rendered, as heretofore, acceptable service.

Respectfully submitted.

C. P. PATTERSON,
Superintendent United States Coast Survey.

Hon. B. H. BRISTOW,
Secretary of the Treasury.

APPENDICES.

ERRATA.

Page 79, in column of table headed "1874," number of soundings should be 743,451, instead of 892; and in column headed "total to December 31, 1874," number of soundings should be 12,793,247, instead of 12,050,688.

APPENDIX No. 1.

Distribution of surveying-parties upon the Atlantic, Gulf, and Pacific coasts of the United States during the surveying-season of 1874–'75.

Coast-sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION I.				
Atlantic coast of Maine, New Hampshire, Massachusetts, and Rhode Island, including sea-ports, bays, and rivers.	No. 1	Hydrography....	Commander John A. Howell, U. S. N., assistant; Lieutenants W. H. Jacques, E. S. Jacob, Richard Rush, and W. L. Field, U. S. N.	Deep-sea soundings in the Gulf of Maine, between the Bay of Fundy and George's Bank. (See also Section VIII.)
	2	Topography and hydrography.	J. W. Donn, assistant; F. C. Donn and F. H. Parsons, aids.	Topography of the northwestern part of Mount Desert Island, and soundings through Eastern Bay, Western Bay, Clark's Cove, and Pretty Marsh Harbor; detailed survey of Egg Rock, in Frenchman's Bay, coast of Maine. (See also Section III.)
	3	Topography	W. H. Dennis, assistant; S. N. Ogden and W. S. Bond, aids.	Plane-table survey of the shores of Eggemoggin Reach, coast of Maine. (See also Section V.)
	4	Topography	J. N. McClintock, subassistant; T. A. Harrison and Walter Fraser, aids.	Detailed survey of numerous islands and ledges adjacent to Isle au Haut and Deer Isle, Penobscot entrance, Me.
	5	Topography	A. W. Longfellow, assistant; W. C. Hodgkins, aid.	Topography of the east side of Penobscot River, above Castine, including part of the north shore of the Bagaduce River, Me.
	6	Topography	Hull Adams, assistant; R. B. Palfrey, aid.	Topographical survey of the shores of Bagaduce River, eastward of Castine Harbor, Me.
	7	Topography	Joseph Hergesheimer, subassistant.	Plane-table survey southward from Bucksport and Orland, Me., including Whitmore's Island and the adjacent shores of Penobscot River. (See also Section VI.)
	8	Hydrography.....	H. Anderson, assistant; Kossuth Niles, master U. S. N., assistant; F. H. North, aid.	Hydrography of the western part of Eggemoggin Reach; and supplementary soundings in Penobscot River and Bay, below Winterport, Me. (See also Section VII.)
		Tides	J. G. Spaulding	Series of tidal and meteorological observations continued at North Haven, Penobscot entrance.
	9	Special observations.	F. W. Perkins, assistant; C. L. Gardner and F. W. Ring, aids.	Co-efficient of refraction determined at Ragged Mountain primary station, near Camden, Me., and heights of the adjacent stations. (See also Section VII.)
	10	Triangulation	Prof. E. T. Quimby	Kearsarge Mountain, Cube Mountain, and Observatory Hill occupied, and subsidiary points determined by triangulation in New Hampshire.
	11	Hydrography.....	Acting Master Robert Platt, U. S. N., assistant; J. B. Adamson, aid.	Hydrographic development, including the vicinity of Isles of Shoals, Jeffrey's Ledge, Cashe's Ledge, Platt's Bank, and Jeffrey's Bank. (See also Section VI.)
		Tides	H. Howland	Series of observations continued at Charlestown navy-yard (Boston) with self-registering tide-gauge.
	12	Hydrography.....	F. D. Granger, subassistant; Lieut. R. D. Hitchcock, U. S. N., assistant; D. C. Hanson, aid.	Soundings extended westward of Monomoy Island to Bishop and Clerk's light-house, and including Chatham Roads, Mass. (See also Section VI.)

APPENDIX No. 1—Continued.

Coast-sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION I—Continued.	No. 13	Triangulation and topography.	A. M. Harrison, assistant; W. H. Stearns and Bion Bradbury, aids.	Points determined on the shores of Taunton River, Mass., and topographical survey advanced from Fall River upward to Somerset.
	14	Special survey	H. L. Whiting, Henry Mitchell, and H. L. Marindin, assistants; J. B. Weir, aid.	Shore-line survey; special observations on currents; transverse sections and soundings in Providence Harbor and Seekonk River for the Harbor Commissioners of Providence, R. I. (See also Sections II and VIII.)
		Tides	....	Observations continued by the city engineer with the self-registering tide-gauge at Providence, R. I.
SECTION II. Atlantic coast and seaports of Connecticut, New York, New Jersey, Pennsylvania, and Delaware, including bays and rivers; and also Lake Champlain.	No. 1	Topography and hydrography.	H. G. Ogden, assistant; D. B. Wainwright, aid.	Topography of the shores of Thames River, Conn., and soundings extended from the naval station near New London upward to Norwich. (See also Section VI.)
	2	Topography	R. M Bache, assistant............	Detailed topographical survey of the shores of New Haven Harbor, Conn., for Harbor Commissioners.
	3	Triangulation	J. A. Sullivan, assistant	Triangulation for determining the positions of light-houses at the eastern entrance of Long Island Sound, N. Y.
	4	Hydrography	J. S. Bradford, assistant; J. R. Barker, draughtsman.	Soundings in the channel near Plum Island, and in the vicinity of Gardiner's Bay, Long Island Sound. Special notes, and views of harbor-entrances between New Haven and New York, compiled, after examination, for the Coast Pilot.
	5	Topography and hydrography.	F. H. Gerdes, assistant; C. P. Dillaway, subassistant; C. A. Ives, aid (part of season).	Detailed survey and soundings, including the vicinity of Port Jefferson (Long Island), N. Y. Topography of the shores of Hackensack River, N. J.
	6	Triangulation.....	Richard D. Cutts, assistant; J. F. Pratt, aid.	Determination of points near the boundary-line between Massachusetts and New York.
	7	Astronomical observations.	George W. Dean, assistant; A. G. Pendleton, aid.	Latitude, azimuth, and meridian line determined at Rouse's Point, N. Y.; latitude and azimuth at Cheever Station, near Port Henry, and at Mount Merino, near Hudson, N. Y.
	8	Topography	C. T. Iardella, assistant; H. W. Bache, subassistant.	Shore-line survey of Lake Champlain from the "Four Brothers" southward to Crown Point, and detailed topography of old military works in that vicinity. (See also Section IV.)
	9	Topography	Andrew Braid, subassistant; C. H. Sinclair, aid.	Shore-line survey of Lake Champlain from Crown Point to Whitehall, N. Y., including topographical details of old military lines at Ticonderoga. (See also Section VIII.)
	10	Hydrography	Charles Junken (part of season); E. H. Wyvill (part of season); G. A. Morrison, aid.	Hydrography of Lake Champlain completed by soundings between Crown Point and Whitehall, N. Y. (See also Section V.)
	11	Station-marks ...	Edward Goodfellow, assistant; C. A. Ives, aid.	Angular measurements for identifying station-points at Weasel Mountain and Beacon Hill, N. J.
	12	Reconnaissance (in progress).	Prof. E. A. Bowser	Preliminaries for determining points by triangulation in the State of New Jersey.
	13	Special hydrography.	Henry Mitchell, assistant; H. L. Marindin, assistant; J. B. Weir, aid.	Transverse curves of velocity determined by observation in the waters of Hudson River and East River, and in the main channel of New York Harbor. (See also Sections I and VIII.)
	14	Hydrography	F. F. Nes, assistant; H. O. Handy, master U. S. N., assistant; W. B. French, aid.	Soundings in West Bank Channel and near Southwest Spit, New York Bay. (See also Section IV.)
		Tides	R. T. Bassett	Tidal and meteorological observations continued at Governor's Island and at Brooklyn, New York Harbor.

APPENDIX No. 1—Continued.

Coast-sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION II—Continued.	No. 15	Topography and hydrography.	Charles Hosmer, assistant; L. B. Wright, subassistant; J. De Wolf, aid.	Topography of the shores, and soundings in Great South Bay, L. I., extended from Islip to Howell's Point. (See also Section VI.)
	16	Topography	C. M. Bache, assistant; H. M. De Wees, subassistant; J. J. Evans, aid.	Detailed survey of the western shores of Barnegat Bay, N. J.
	17	Hydrography	W. I. Vinal, subassistant; E. B. Pleasants, aid.	Barnegat Bay, N. J., thoroughly sounded; and hydrography of the entrance and approaches to Little Egg Harbor. (See also Section IX.)
	18	Reconnaissance (in progress).	Prof. L. M. Haupt	Preliminaries for determining points by triangulation in the eastern part of Pennsylvania.
	19	Triangulation	J. A. Sullivan, assistant; C. L. Gardner, aid.	Triangulation across the Delaware River, in the vicinity of Liston's Tree.
	20	Hydrography	F. F. Nes, assistant; C. H. Sinclair and R. B. Palfrey, aids.	Soundings in the channel of Delaware River at Liston's Tree, and selection of positions for range-beacons as aids to navigation.
	21	Hydrography	Charles Junken	Hydrographic resurvey of the entrance to Schuylkill River, and positions determined for range-lights, as aids to navigation. (See also Section V.)
SECTION III. Atlantic coast and bays of Maryland and Virginia, including sea-ports and rivers.	1	Topography and hydrography.	J. W. Donn, assistant; F. C. Donn, F. H. Parsons, D. C. Hanson, and C. A. Ives, aids.	Topographical survey of Craney Island, Va., for the Ordnance Bureau, Navy Department. Survey of the shores and hydrography of James River, Va., from Sloop Point to City Point. Topography of shores, and soundings in Chickahominy River, Va., from Ship-Yard upward to Forge Bridge. (See also Section I.)
	2	Hydrography	J. B. Baylor, aid	Soundings in the channel between Craney Island and the Virginia shore.
		Tides	W. J. Bodell	Series of observations continued at Fortress Monroe with self-registering tide-gauge.
		Magnetic observations.	Charles A. Schott, assistant	Magnetic declination, dip, and intensity determined at the standard station on Capitol Hill, Washington, D. C.
	3	Triangulation	A. T. Mosman, assistant; D. S. Wolcott, aid; C. L. Gardner, aid (part of season).	Mount Marshall and Fork Mountain occupied for primary triangulation in Virginia. Observations in progress at Humpback Mountain.
	4	Reconnaissance ...	S. C. McCorkle, assistant	Selection of stations for a chain of triangles through West Virginia. (See also Section VII.)
SECTION IV. Atlantic coast and sounds of North Carolina, including sea-ports and rivers.	1	Triangulation	G. A. Fairfield, assistant; B. A. Colonna, subassistant; W. B. Fairfield, aid.	Pamplico Sound triangulation extended north and east, and completed by connecting with the base-line on Bodie's Island, N. C. Light-houses at Cape Hatteras, at Croatan Sound, and at Currituck Beach, determined in position.
	2	Topography	C. T. Iardella, assistant; H. W. Bache, subassistant.	Survey of the western shore of Pamplico Sound from Roanoke Marshes light-house southward to Juniper Bay. (See also Section II.)
	3	Hydrography	Lieut. H. O. Handy, U. S. N., assistant; Masters W. P. Ray and F. H. Lefavor, U. S. N.	Hydrography of the west side of Pamplico Sound from Shoal Point southward, and including Yesocking Bay. (See also Section II.)
SECTION V. Atlantic coast and sea-water channels of South Carolina and Georgia, including sounds, harbors, and rivers.	1	Topography and hydrography.	W. H. Dennis, assistant; S. N. Ogden and W. S. Bond, aids.	Topographical survey of the coast of South Carolina from Cape Romain southward to Sullivan's Island, including the shores of Bull's Bay, and soundings in the sea-water channels adjacent to the coast. (See also Section I.)
	2	Topography	Charles Junken	Shore-line survey developing the extent of sea-encroachment at Hunting Island, Saint Helena Sound, S. C. (See also Section II.)

APPENDIX No. 1—Continued.

Coast-sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION V—Continued.	No. 3	Hydrography	Lieut. J. M. Hawley, U. S. N., assistant; Ensigns J. M. Wight and G. C. Hanus, U. S. N.	Soundings in Savannah River, Ga., developing the bar and channel upward to the head of Elba Island.
	4	Triangulation	C. O. Boutelle, assistant; H. W. Blair and J. B. Boutelle, aids.	Geodetic observations at Grassy Mountain, Skitt Mountain, and Currahee Mountain, Ga. Latitude, azimuth, and the magnetic elements determined.
	5	Reconnaissance	S. C. McCorkle, assistant; H. Anderson, assistant.	Stations selected in Northern Alabama to connect with the chain of triangles in Upper Georgia. (See also Section III.)
	6	Reconnaissance (in progress).	Prof. W. B. Page	Preliminaries for determining points by triangulation in the southeastern part of the State of Kentucky.
	7	Reconnaissance	R. E. Halter, assistant	Reconnaissance in Northern Kentucky and Ohio for points of triangulation near the Ohio River.
SECTION VI. Atlantic and part of the Gulf coast of the Florida peninsula, including reefs and keys, and the seaports and rivers.	1	Hydrography	Lieut. R. D. Hitchcock, U. S. N., assistant; Masters Jas. Franklin and John Hubbard, U. S. N.; Ensigns H. T. C. Nye and J. L. Hunsicker, U. S. N.	Coast-hydrography extended southward across Saint Augustine entrance to Matanzas Inlet; special development off that inlet; and examination of the channel into Saint Augustine. (See also Section I.)
	2	Triangulation, topography, and hydrography.	Charles Hosmer, assistant; L. B. Wright, subassistant; J. De Wolf and T. A. Harrison, aids.	Detailed survey of the Florida coast and parts adjacent, and soundings in the water-passages south of Mosquito Inlet, including the head of Indian River. (See also Section II.)
	3	Triangulation, topography, and hydrography.	H. G. Ogden, assistant; Joseph Hergesheimer, subassistant; D. B. Wainwright, G. A. Morrison, and W. B. French, aids.	Triangulation and topographical survey of the Tortugas Islands. Detailed survey of the shores and hydrography of Tampa Bay, Fla. (See also Section II.)
	4	Hydrography	Acting Master Robert Platt, U. S. N., assistant; J. B. Adamson, aid.	Soundings completed in the vicinity of Tortugas Reef, including the Harbor. Hydrography of the entrance and Gulf approaches to Tampa Bay, Fla. (See also Section I.)
		Tides	M. Kruse	Tidal observations with self-registering gauge continued at Saint Thomas, West Indies.
SECTION VII. Gulf coast and the sounds of West Florida, including ports and rivers.	1	Triangulation, topography, and hydrography.	F. W. Perkins, assistant; J. F. Pratt, F. W. Ring, and A. G. Pendleton, aids.	Detailed survey of the coast of Florida, and inshore soundings completed between Cedar Keys and Ocilla River. (See also Section I.)
	2	Hydrography	Master Kossuth Niles, U. S. N., assistant; H. O. Rittenhouse, Alexander McCrackin, and H. W. Schaefer, masters, U. S. N.	Hydrography of the Gulf coast from Saint George light-house to Saint Andrew's Point, including the shoals off Cape San Blas; and the hydrography of Saint Joseph's Bay (north). (See also Section I.)
	3	Triangulation and astronomical observations.	F. P. Webber, assistant; F. D. Granger, subassistant; J. H. Christian and Charles Tappan, aids.	Pine Log Mountain, Lavender Mountain, and John's Mountain, Ga., occupied as points in a chain of primary triangles westward of the Atlantic base-line. Latitude, azimuth, and the magnetic elements determined.
SECTION VIII. Gulf coast and bays of Alabama, and the sounds of Mississippi and of Louisiana to Vermilion Bay, including the ports and rivers.	1	Special survey and hydrography.	Henry Mitchell, assistant; H. L. Marindin, assistant; J. B. Weir and Bion Bradbury, aids.	Development of the physical hydrography of South Pass, including observations on the density of water at the mouths of the Mississippi, and on the currents of the river and bar. (See also Sections I and II.)
	2	Hydrography	Commander John A. Howell, U. S. N., assistant (part of season); Lieut. Commander C. D. Sigsbee, U. S. N., assistant; Lieuts. C. T. Hutchins, J. W. Hagenman, and James M. Grimes, U. S. N.; Master R. G. Peck, U. S. N., and Ensign W. E. Sewell, U. S. N.	Lines of soundings in the Gulf of Mexico radiating from the Mississippi Delta; and deep-sea lines run from Southwest Pass to the Rio Grande entrance, and from thence to the Tortugas. (See also Section I.)

APPENDIX No. 1—Continued.

Coast-sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION VIII—Continued.	No. 3	Triangulation and topography.	C. H. Boyd, assistant; Andrew Braid, subassistant; C. H. Van Orden and W. E. McClintock, aids.	Detailed survey of the banks of the Mississippi River from the battle-ground upward to Kennerville, including New Orleans, Algiers, Gretna, McDonoughville, and Carrollton, La. Determination of points in Missouri by a chain of triangles westward to the vicinity of the Gasconade River.
	4	Reconnaissance...	Prof. John E. Davies	Preliminary measurement of a base-line at Spring Green, Wis., and arrangements for triangulation along the Wisconsin River.
SECTION IX. Gulf coast of Western Louisiana and of Texas, including bays and rivers.	1	Hydrography	W. I. Vinal, subassistant; Lieut. Richard Wainwright, U. S. N., assistant; E. H. Wyvill and E. B. Pleasants, aids.	Hydrography completed in San Antonio Bay, Musquit Bay, and Aransas Bay. Progress in soundings in Lamar, Copano, and Saint Charles Bays, Tex. (See also Section II.)
SECTION X. Coast of California, including the bays, harbors, and rivers.	1	Triangulation, topography, and hydrography.	A. W. Chase, assistant; Eugene Ellicott, subassistant; F. A. Lawson, aid.	Detailed survey of the coast of California adjacent to Newport Bay, near Point Lasuen, and hydrographic development of the approaches and channel of the bay.
	2	Topography	Stehman Forney, assistant........	Topographical survey completed on Santa Cruz Island, Cal.
	3	Hydrography	Lieut. Commander H. C. Taylor, U. S. N., assistant; Lieuts. George Talcott, Frank Courtis, Richardson Clover; J. D. Adams, and G. W. Tyler, U. S. N.	Hydrography of the north and south approaches to Santa Cruz Island, off the coast of California; development of a shoal off the South Farallon Light-House; buoys placed on Noonday Rock.
	4	Triangulation....	O. H. Tittmann, subassistant; W. S. Edwards, aid.	Angular measurements at Gaviota, coast of California, for determining the positions of points on San Miguel Island and Santa Cruz Island.
	5	Hydrography.....	L. A. Sengteller, assistant; F. Westdahl, aid.	Hydrography of San Luis Obispo Bay, Cal., including the determination in position, and the development of dangers to navigation near Point San Luis.
	6	Topography	Cleveland Rockwell, assistant.....	Detailed topographical survey, including Point Sur and Morro Rock, coast of California, for the uses of the Light-House Board. (See also Section XI.)
	7	Hydrography....	Gershom Bradford, assistant; F. Westdahl, aid.	Soundings in San Francisco Bay abreast of Saucelito, and between Yerba Buena and Oakland; series of current observations continued in the bay; in-shore hydrography completed between Cape Mendocino and Rocky Point, including the vicinity of a dangerous rock found in the channel between Blunt's Reef and Cape Mendocino.
		Tides	Col. G. H. Mendell, United States Engineers; E. Gray, observer.	Tidal series continued at Fort Point, Cal., with self-registering tide-gauge. (See also Section XI.)
	8	Reconnaissance...	William Eimbeck, assistant; T. J. Lowry, aid.	Reconnaissance for stations intervisible as points in a chain of triangles eastward of Mount Shasta and the Sierra Nevada range.
	9	Topography	A. F. Rodgers, assistant; E. F. Dickins, aid.	Topography of the coast of California north and south of Ten-Mile River, completing the detailed survey between Point Cabrillo and Shelter Cove; measurement of a verification base.
	10	Triangulation	A. W. Chase, assistant	Triangulation completed along the coast of California between Rocky Point and Klamath River, including the vicinity of Redding's Rock.
	11	Hydrography....	Lieut. Commander H. C. Taylor, U. S. N., assistant; Lieuts. George Talcott, F. Courtis, Richardson Clover, J. D. Adams, and G. W. Tyler, U. S. N.	In-shore hydrography of the coast of California and Oregon in the vicinity of the boundary completed, from False Klamath northward to Mack's Arch, in Section XI; development of dangers to navigation and of a harbor of refuge near Mack's Arch.

APPENDIX No. 1—Continued.

Coast-sections.	Parties.	Operations.	Persons conducting operations.	Localities of work.
SECTION X—Continued.	No. 12	Reconnaissance...	A. F. Rodgers, assistant	Region and summit of Mount Shasta, Cal., examined as a center available for primary triangulation.
SECTION XI.				
Coast of Oregon and of Washington Territory, including the interior bays and the ports and rivers.	1	Hydrography.....	Lieut. Commander H. C. Taylor, U. S. N., assistant.	In-shore soundings from the lower boundary of Oregon northward to Mack's Arch. (See also Section X.)
	2	Triangulation and topography.	J. J. Gilbert, assistant; F. Westdahl, aid.	Triangulation and plane-table survey of the coast of Oregon from Point Adams southward to the entrance of Nehalem River.
	3	Topography......	Cleveland Rockwell, assistant; G. H. Wilson, aid.	Topographical survey of the shores of Columbia River, Oreg., extended upward from Oak Point to Smith's Island. (See also Section X.)
		Tides.............	Col. G. H. Mendell, United States Engineers; L Wilson, observer.	Series of observations continued at Astoria, Oreg., with self-registering tide-gauge. (See also Section X.)
	4	Triangulation and topography.	James S. Lawson, assistant; T. P. Woodward, aid (part of season); F. A. Lawson, aid (part of season).	Detailed topographical survey of the eastern shores of Duwamish Bay, W. T., including the town of Seattle and part of Lake Union.
		Tides.............	Col. G. H. Mendell, United States Engineers; L. Nessel, observer.	Tidal and meteorological observations continued at Port Townshend, W. T. (See also Section X.)
SECTION XII.				
Coast, harbors, and islands of Alaska Territory.	1	Astronomical observations, triangulation, topography, and hydrography.	W. H. Dall, acting assistant; Marcus Baker, aid.	Surveys of numerous harbors and anchorages on the coast of Alaska; determinations of latitude, azimuth, and the magnetic elements, and of the heights of Mount Crillon, Mount Fairweather, Mount Saint Elias, and other prominent landmarks.
Nagasaki, in Japan........	....	Astronomical.....	Prof. George Davidson, assistant, chief observer; O. H. Tittmann, subassistant; W. S. Edwards, aid.	Observations recorded during the Transit of Venus, December 8, 1874; latitude and longitude determined at the observing-station, Nagasaki, Japan.
Chatham Island, in the South Pacific Ocean.	....	Astronomical.....	Edwin Smith, subassistant, chief observer; A. H. Scott, aid.	Observations recorded on the Transit of Venus December 8, 1874, at Chatham Island; latitude and longitude determined at the observing-station.

APPENDIX No. 2.

Statistics of field and office work of the United States Coast Survey during the year 1874.

Description.	Previous to January 1, 1874.	1874.	Total to December 31, 1874.
RECONNAISSANCE.			
Area in square miles	94, 500	6, 050	110, 550
Parties, number of	61	2	63
BASE-LINES.			
Primary, number of	13	....	13
Secondary, number of	94	3	97
Length of, in miles, (primary)	79	....	79
Length of, in miles, (secondary, including line measures)	219½	4½	224
TRIANGULATION.			
Area in square miles	65, 833	5, 747	71, 580
Horizontal-angle stations occupied	7, 759	281	8, 040
Geographical positions determined	14, 499	492	14, 991
Vertical-angle stations occupied, number of	420	12	432
Elevations determined, number of	925	38	963
Parties, number of	377	27	404
ASTRONOMICAL OPERATIONS.			
Stations occupied for azimuth	127	7	134
Stations occupied for latitude	230	7	237
Stations occupied for longitude	317	2	319
Parties, number of	83	8	91
Magnetical stations occupied, number of	358	19	377
Parties, number of	76	5	81
TOPOGRAPHY.			
Area surveyed in square miles	23, 505	1, 227	24, 732
Length of general coast in miles	5, 491	155	5, 646
Length of shore-line in miles, including rivers, creeks, and ponds	65, 581	3, 329	68, 910
Length of roads in miles	34, 791	1, 310	36, 101
Parties, number of	352	21	373
HYDROGRAPHY.			
Parties, number of	260	29	289
Number of miles run while sounding	266, 696½	11, 213	277, 909½
Area sounded in square miles	66, 596	1, 609	68, 205
Miles run additional of outside or deep-sea soundings	39, 933	4, 438	44, 371
Number of soundings	12, 049, 796	892	12, 050, 688
Soundings in Gulf Stream for temperature	4, 072	....	4, 072
Tidal stations, permanent	184	9	193
Tidal stations, occupied temporarily	1, 424	70	1, 494
Tidal parties, number of	288	41	329
Current stations occupied	55	102	157
Current parties	3	6	9
Specimens of bottom, number of	9, 837	557	10, 394
RECORDS.			
Triangulation, originals, number of volumes	1, 710	130	1, 840
Astronomical observations, originals, number of volumes	992	122	1, 114
Magnetical observations, originals, number of volumes	314	9	323
Duplicates of the above, number of volumes	2, 101	5	2, 106
Computations, number of volumes	2, 023	122	2, 145
Hydrographical soundings and angles, original, number of volumes	6, 080	355	6, 435
Hydrographical soundings and angles, duplicates, number of volumes	525	83	608
Tidal and current observations, originals, number of volumes	2, 434	109	2, 543
Tidal and current observations, duplicates, number of volumes	1, 811	35	1, 846

APPENDIX No. 2—Continued.

Description.	Previous to January 1, 1874.	1874.	Total to December 31, 1874.
RECORDS—Continued.			
Sheets from self-registering tide-gauges, number of	2,142	108	2,250
Tidal reductions, number of volumes	1,527	38	1,565
Total number of volumes of records	19,517	1,008	20,525
MAPS AND CHARTS.			
Topographical maps, originals	1,344	75	1,419
Hydrographic charts, originals	1,232	92	1,324
Reductions from original sheets	749	16	765
Total number of manuscript maps and charts to and including 1874	2,517	9	2,526
Number of sketches made in field and office	2,785	50	2,835
ENGRAVING AND PRINTING.			
Engraved plates of finished charts, number of	184	11	195
Engraved plates of preliminary charts, sketches, and diagrams for the Coast Survey Reports, number of.	552	8	560
Electrotype-plates made	1,043	47	1,090
Finished charts published	168	9	177
Preliminary charts and hydrographical sketches published	453	11	464
Printed sheets of maps and charts distributed	306,851	19,425	326,276
Printed sheets of maps and charts deposited with sale-agents	111,455	7,697	119,152
LIBRARY.			
Number of volumes	5,562	95	5,657
INSTRUMENTS.			
Cost of	$91,418 73	$10,976 09	$102,394 82

APPENDIX No. 3.

Information furnished from the Coast-Survey Office, by tracings from original sheets, &c., in reply to special calls, to July, 1875.

Date.		Name.	Data furnished.
1874.			
October	28	Charles F. Frill, civil engineer	Hydrographic information of harbor of Baltimore, Md.
	29	Col. Theodore Lyman	Topographical survey of the shores of Buttermilk Bay, head of Buzzard's Bay, Mass.
November	27	W. I. Miller, Somerset County, Pa	Magnetic variations in Western Pennsylvania.
	30	S. T. Abert, United States civil engineer	Topographical survey of the shore of Chesapeake Bay, between the Little and Great Wicomico Rivers, Va.
December	16	Hon. Lorenzo Danford	Magnetic variations in Southeastern Ohio.
	24	Hon. R. W. Hughes, United States district judge, eastern district of Virginia.	Comparative descriptions of Hampton Roads and Portland Harbor.
	28	Hydrographic bureau, empire of Japan	Azimuth and altitudes of Polaris and transit-star places.
	31	Col. R. S. Williamson	Topographical survey of Point St. George, Cal.
1875.			
January	8	S. T. Abert, United States civil engineer	Hydrographic survey of approaches to Little Wicomico River, Va.
	8	do	Hydrographic survey of Totouskey Creek, Rappahannock River, Va.
	13	do	Hydrographic survey of the Great Wicomico River, Va.
	14	Prof. C. G. Forchey, New Orleans	Line of soundings across the Yucatan Channel.
	15	Internal improvement committee, North Carolina house of representatives.	Topography and hydrography of Beaufort and vicinity, N. C., including Clubfoot Creek Canal.
	16	Mayor of Savannah, Ga	Hydrographic survey of the city front, from the Gulf Railroad wharf to the Central Railroad wharf.
	19	G. Danbeney, civil engineer	Hydrographic survey of mouth of Hannah Mills Creek, Saint John's River, Fla.; also, magnetic variation in the same locality.
	21	Noble Carter, county surveyor, Clarkesville, Ohio	Magnetic declination at various places.
	25	Nelson Beale, esq	Topographical survey of Paramore's Island, sea-coast of Virginia.
	26	Capt. James B. Eads	Topographical survey of South Pass, Mississippi Delta.
February	10	Durant and Horner, Washington City	Topographical and hydrographic survey of the Mississippi River, from Polites flag-staff to Magnolia sugar-house.
	13	Gen. W. W. Wright	Magnetic declination at Harrisburg, Pa., in 1822.
	24	S. T. Abert, United States civil engineer	Hydrographic survey, on $\frac{1}{10000}$ scale, of Pagan Creek, James River, Va.
March	5	Hon. Henry H. Starkweather, M. C	Topographical and hydrographic survey of Norwich and vicinity, Conn.
	6	Bureau of Ordnance, Navy Department	Copy of topographical survey of Craney Island, scale $\frac{1}{1200}$.
	8	E. Dexter, esq., Providence, R. I	Topographical and hydrographic survey of the eastern shore of Providence River, from Nayat Point to East Providence.
	13	Edwin F. Kittoe, esq	Hydrographic survey of Beaufort River and Brickyard Creek, S. C.
	18	Bureau of Engineers, United States Army	Hydrographic survey of the channels leading to Boston, Mass.
	22	Internal improvement committee, North Carolina house of representatives.	Topographical and hydrographic surveys, coast of North Carolina, from Fort Macon to Bogue Inlet, including Newport River to the Narrows.
	26	Bureau of Engineers, United States Army	Hydrographic survey of the channels leading to Portland, Me.
	26	do	Hydrographic survey of Newport Harbor, R. I.
April	8	S. T. Abert, United States engineer	Hydrographic survey of the Eastern Branch of the Potomac River, from United States navy-yard to Bladensburg.
	8	do	Hydrographic survey of Edenton Bay, N. C.
	9	Alex. Agassiz, esq	Topographical survey of Castle Hill and vicinity, entrance to Narragansett Bay, R. I.
	15	Ambrose W. Thompson, president International Steamship Company.	Topographical survey of Newport News Point, Va.
	16	Bureau of Engineers, United States Army	Hydrographic survey of the Potomac River, between Forts Washington and Foote.
	16	do	Hydrographic survey of Hampton Roads, Va.
	16	do	Hydrographic survey of Pensacola Harbor, Fla.

APPENDIX No. 3—Continued.

Date.		Name.	Data furnished.
1875.			
April	16	Bureau of Engineers, United States Army	Hydrographic survey of entrance to Mobile Bay, Ala.
	16	........do	Hydrographic survey of Savannah River, Ga.
	16	........do	Hydrographic survey of New London Harbor, Conn.
	17	John Punnett, esq	Hydrographic survey of the Hackensack River, from Newark Bay to the town of Hackensack.
	20	Justus Roe, esq	Hydrographic survey of Great South Bay, from Nicoll's Point to Howell's Point, Long Island, N. Y.
May	8	William W. Harding, esq., Philadelphia	Hydrographic survey of the Delaware River, from Richmond to Bridesburg.
	13	Bureau of Yards and Docks, Navy Department	Hydrographic survey of the Thames River, from naval station to Clark's Cave, Conn.
	13	Hon. George A. Halsey, New Jersey	Hydrographic survey of the Passaic River, from Morris's Turnpike Bridge to and including city front of Newark, N. J.
	14	Capt. W. S. Stanton, chief engineer, Department of the Platte.	Latitude and longitude of Omaha, Nebr.
	19	Advisory board on harbor of Norfolk, Va	Hydrographic survey of Norfolk Harbor and adjacent waters.
	19	Lieut. Col. F. W. Reynolds, light-house engineer, fourth district.	Hydrographic survey of the Schuylkill River, from the bar to Penrose bridge.
	31	Franklin A. Stratton, civil engineer, United States Navy.	Hydrographic survey of the Thames River, from upper limits of published chart to southern boundary-line of naval station.
June	1	United States Light-House Board	Hydrographic survey of the Schuylkill River, from the bar to Penrose bridge.
	2	L. B. Ward, esq	Topographical survey of Snake Hill, Hackensack River, N. J.
	10	Franklin A. Stratton, civil engineer, United States Navy.	Shore-line survey of Thames River, opposite naval station.
	23	Gulf Western Texas Railroad	Hydrographic survey of Pass Cavallo, Tex.
	30	Marius Schoonmaker, New York	Hydrographic survey of the Hudson River, from Turkey Point to Saugerties Creek.

APPENDIX No. 4.

DRAWING DIVISION.

Charts completed or in progress from September 30, 1874, to July 1, 1875.

1. Hydrography. 2. Topography. 3. Drawing for photographic reduction. 4. Details in photographic outlines. 5. Verification. 6. Lettering.

Title of chart.	Scale.	Draughtsmen.	Remarks.
General coast chart No. I, Quoddy Head, Me., to Cape Cod, Mass.	1-400,000	2. A. Lindenkohl	Additions.
Coast chart No. 3, Petit Manan light to Naskeag Point, Me.	1-80,000	3. H. Lindenkohl. 3. C. A. Meuth. 4. P. Erichsen. 5. P. Erichsen.	
Coast chart No. 4, Naskeag Point to White Head light, including Penobscot Bay, Me.	1-80,000	1. A. Lindenkohl. 3. L. Karcher. 3. P. Erichsen. 3. C. A. Meuth. 4. P. Erichsen.	
Belfast Bay and Penobscot River, Me	1-40,000	1. A. Lindenkohl	
Coast chart No. 6, Seguin Island light to Wood Island light, Me.	1-80,000	2. H. Lindenkohl	
Richmond Island Harbor, Me	1-20,000	1. A. Lindenkohl	New edition; completed.
Isles of Shoals, N. H	1-20,000	1. F. Fairfax	Do.
Rockland Harbor, Me	1-20,000	1, 2. A. Lindenkohl. 5. P. Erichsen	Do.
Newport and vicinity, R. I	1-12,000	1. L. Karcher. 1. P. Erichsen. 2. C. A. Meuth.	Photolithograph.
Passaic River, near Newark, N. J	1-6,000	1, 2, 6. C. A. Meuth	Photolithograph; completed.
Raritan River, sheet No. 1, South Amboy to Crabb Island, N. J.	1-15,000	1, 2, 6. H. Lindenkohl	Do.
Raritan River, sheet No. 2, Crabb Island to New Brunswick, N. J.	1-15,000	1, 2, 6. H. Lindenkohl	Do.
Coast chart No. 20, New York Bay and Harbor	1-80,000	1. A. Lindenkohl	New edition of hydrography.
New Haven Harbor, Conn	1-20,000	1. C. Junken	Completed.
New York Bay and Harbor, (lower sheet)	1-40,000	1. H. Lindenkohl. 2. C. A. Meuth	Additions; completed.
Fire Island Inlet, N. Y	1-30,000	1, 2, 6. A. Lindenkohl	
Coast chart No. 21, Sandy Hook to Barnegat light, N. J	1-80,000	2. A. Lindenkohl	
Coast chart No. 22, Barnegat Bay to Absecom light, N. J	....	2. A. Lindenkohl. 2. H. Lindenkohl	
Potomac River, Indian Head to Little Falls Bridge	....	2. A. Lindenkohl. 6. H. Lindenkohl	Addition; completed.
Craney Island, Va	1-1,200	2. P. Erichsen. 2. F. Fairfax	Special map; completed.
Norfolk Harbor, Elizabeth River and branches	1-25,000	1, 2. A. Lindenkohl. 1, 2, 6. H. Lindenkohl. 2. M. Angles.	Photolithograph; completed.
Coast chart No. 41, Albemarle Sound, (western part)	1-80,000	1. H. Lindenkohl	Additions; completed.
General coast chart No. V, Cape Charles to Lookout, N. C	1-400,000	2. A. Lindenkohl	Additions.
Coast chart No. 42, Roanoke Island to Hatteras Inlet, N. C	1-80,000	1. H. Lindenkohl	
Coast chart No. 43, Pamlico Sound, Ocracoke Inlet, to mouth of Pamplico River, N. C.	1-80,000	1. H. Lindenkohl. 2. H. Lindenkohl	
Coast chart No. 44, Pamplico and Neuse Rivers, N. C	1-80,000	1. H. Lindenkohl	Additions; completed.
Core Sound and Straits	1-40,000	1, 2. H. Lindenkohl	Do.
Beaufort Harbor, N. C	1-40,000	1, 2, 6. A. Lindenkohl. 2. H. Lindenkohl	New edition; completed.
Inside Passage between Broad and Coosaw Rivers, S. C	1-40,000	2. P. Erichsen	Additions; completed.
Atlanta base and vicinity, Ga., triangulation of	1-600,000	A. Lindenkohl	Completed.
Sawpit and Sister Creeks, Fla	1-15,000	1, 2. F. Fairfax	
Coast chart No. 90, Round Island to Grand Island, Mississippi Sound.	1-80,000	1. H. Lindenkohl	Additions; completed.
Pass Cavallo, Tex	1-15,000	1, 2, 6. C. A. Meuth	
Catalina Harbor and Isthmus Cove, Cal	1-15,000	1, 2, 6. H. Lindenkohl	Photolithograph; completed.
Pacific Coast, No. 2, Point Vincent to Point Concepcion, Cal	1-200,000	H. Lindenkohl, engraving topography	
San Francisco Bay and entrance, Cal	1-50,000	1. L. Karcher. 2. A. Lindenkohl	Additions.
Saint George's Reef and Crescent City, Cal	1-40,000	1. H. Lindenkohl	Additions; completed.
Hunter's Cove, Oreg	1-12,500	1. L. Karcher. 1. H. Lindenkohl. 2. H. Lindenkohl.	Photolithograph; completed.
Mack's Shelter, Oreg	1-25,000	1. L. Karcher. 1, 2. M. Angles. 2. H. Lindenkohl.	Do.
Columbia River, (sheet No. 1)	1-40,000	2. L. Karcher	Additions.
Columbia River, (sheet No. 2)	1-40,000	2. A. Lindenkohl	Do.
Diagram of tides, coast of Alaska	....	2, 6. L. Karcher	Completed.

APPENDIX No. 4—Continued.

Title of chart.	Scale.	Draughtsman.	Remarks.
PHOTOLITHOGRAPHIC CHARTS.			
Harbors in Alaska.			
Southwest anchorage, Chirikoff Island	....	1, 2, 6. H. Lindenkohl	Completed.
Saint George Island, Pribiloff Islands, Bering Sea	....	1, 2, 6. H. Lindenkohl	Do.
Pribiloff Islands, Bering Sea	....	1, 2, 6. H. Lindenkohl	Do.
Simeonoff Harbor, Simeonoff Island, Shumagins	....	1, 2, 6. H. Lindenkohl	Do.
Northeast Harbor, Shumagin Island	....	1, 2, 6. H. Lindenkohl	Do.
Eagle Harbor, Nagai Island, Shumagins	....	1, 2, 6. H. Lindenkohl	Do.
Falmouth Harbor, Nagai Island, Shumagins	....	1, 2, 6. H. Lindenkohl	Do.
Kyska Harbor, Great Kyska Island, Aleutian Islands	....	1, 2, 6. H. Lindenkohl	Do.
Sannakl Islands and reefs	....	1, 2, 6. H. Lindenkohl	Do.
Acherk Harbor, Sannakl Islands	....	1, 2, 6. H. Lindenkohl	Do.
Northwest and Yakon Harbors, Shumagin Islands	....	1, 2, 6. H. Lindenkohl	Do.
Middleton Island	....	1, 2, 6. H. Lindenkohl	Do.
Saint Matthew and adjoining islands	....	1, 2, 6. H. Lindenkohl	Do.
Semidi Islands, Chirikoff Island and Lighthouse Rocks	....	1, 2, 6. H. Lindenkohl	Do.
Anchorage at Cape Etolin, Nunivak Islands, Bering Sea	....	1, 2, 6. H. Lindenkohl	Do.
Lituya Bay	....	1, 2, 6. H. Lindenkohl	Do.
Entrance to Lituya Bay	....	1, 2, 6. H. Lindenkohl	Do.
Port Mulgrave, Yakutat Bay	....	1, 2, 6. H. Lindenkohl	Do.
Shumagin Islands	....	1, 2, 6. H. Lindenkohl	Do.
Saint Paul Island, Pribiloff Island, Bering Sea	....	1, 2, 6. H. Lindenkohl	Do.
Bay of Islands, Adakh Island, Aleutians	....	1, 2, 6. H. Lindenkohl	Do.
Constantine Harbor, Amchuitka Island, Aleutians	....	1, 2, 6. H. Lindenkohl	Do.
Anchorage Chiachi Islands, Aliaska Peninsula	....	1, 2, 6. H. Lindenkohl	Do.
Port Möller, north side Aliaska Peninsula, Bering Sea	....	1, 2, 6. H. Lindenkohl	Do.
Iliuliuk Harbor, Unalashka	....	1, 2, 6. H. Lindenkohl	Do.
Saint Elias, Alpine region	....	1, 2, 6. H. Lindenkohl	Do.
Anchorage Chignik Bay, Aliaska Peninsula	....	1, 2, 6. H. Lindenkohl	Do.
Captain's Bay and vicinity, Unalashka Island	....	1, 2, 6. H. Lindenkohl	Do.
Mount Saint Elias and Coast Range to Cape Spencer	....	1, 2, 6. H. Lindenkohl	Do.

APPENDIX No. 5.

ENGRAVING DIVISION.

Plates completed, continued, or commenced October 1, 1874, to July 1, 1875.

1. Outlines. 2. Topography. 3. Sanding. 4. Lettering.

Title of plates.	Scale.	Engravers.
COMPLETED.		
Coast-charts.		
No. 29, Chincoteague Inlet to Hog Island	1-80, 000	4. F. Courtenay, J. G. Thompson, and A. Petersen.
No. 30, Hog Island to Cape Henry	1-80, 000	4. E. A. Maedel, J. G. Thompson, and A. Petersen.
No. 86, Choctawhatchee Inlet to Pensacola entrance	1-80, 000	4. E. A. Maedel and J. G. Thompson.
No. 94, Mississippi River Passes to Grand Prairie	1-80, 000	4. E. A. Maedel.
Harbor-charts.		
Belfast Harbor	1-20, 000	2 and 4. W. H. Knight.
Little Egg Harbor	1-40, 000	4. J. G. Thompson and E. H. Sipe.
Saint Andrew's Sound	1-40, 000	2. R. F. Bartle. 4. J. G. Thompson and W. H. Davis.
Entrance to Saint Mary's River and Fernandina Harbor	1-20, 000	4. A. Petersen and J. G. Thompson.
Trinidad Harbor	1-15, 000	1 and 2. R. F. Bartle. 3. W. A. Thompson. 4. J. G. Thompson and W. H. Knight.
CONTINUED.		
General coast-charts.		
No. I, western part, from Isle au Haut to Cape Cod	1-400, 000	4. E. A. Maedel.
No. V, from Cape Henry to Cape Lookout	1-400, 000	2. A. M. Maedel. 4. A. Petersen.
No. VII, from Cape Romain to Amelia Island	1-400, 000	4. E. A. Maedel and A. Petersen.
No. XIII, from Cape San Blas to Mississippi Passes	1-400, 000	2. A. M. Maedel. 4. E. A. Maedel and A. Petersen.
Santa Barbara Channel No. 2	1-200, 000	2. H. Lindenkohl.
Coast-charts.		
No. 3, Frenchman's and Blue Hill Bays	1-80, 000	1 and 2. J. Enthoffer. 4. E. A. Maedel.
No. 4, Penobscot Bay	1-80, 000	1 and 2. J. Enthoffer. 4. E. A. Maedel.
No. 6, Kennebec entrance to Saco River	1-80, 000	1. J. Enthoffer. 2. J. Enthoffer and W. A. Thompson.
No. 7, Kennebec entrance to Cape Porpoise	1-80, 000	1 and 2. J. Enthoffer and W. A. Thompson. 4. E. A. Maedel.
No. 20, New York Bay and Harbor	1-80, 000	1 and 2. H. C. Evans. 4. E. A. Maedel.
No. 40, Albemarle Sound (eastern sheet)	1-80, 000	4. A. Petersen.
No. 41, Albemarle Sound (western sheet)	1-80, 000	1. A. M. Maedel. 2 and 3. W. A. Thompson. 4. A. Petersen.
No. 54, Long Island to Hunting Island	1-80, 000	2. A. Sengteller and W. A. Thompson. 3. H. M. Knight. 4. E. A. Maedel.
No. 55, Hunting Island to Ossabaw Sound	1-80, 000	2. A. Sengteller and W. A. Thompson. 3. H. M. Knight. 4. E. A. Maedel.
No. 56, Savannah to Sapelo Island	1-80, 000	3. H. M. Knight. 4. E. A. Maedel.
No. 57, Sapelo Island to Amelia Island	1-80, 000	3. H. M. Knight. 4. E. A. Maedel.
No. 58, Cumberland Sound to Saint John's River	1-80, 000	2. A. Sengteller. 4. E. A. Maedel.
No. 107, Matagorda Bay	1-80, 000	4. E. A. Maedel.
No. 108, Pass Cavallo and San Antonio Bay	1-80, 000	1. H. M. Knight. 2. R. F. Bartle. 4. E. A. Maedel.
No. 109, Aransas and Copano Bays	1-80, 000	1. H. M. Knight. 4. E. A. Maedel.
Pamplico River (1874 edition)	1-80, 000	3. H. M. Knight. 4. A. Petersen.
Harbor-charts.		
Frenchman's Bay	1-40, 000	1. E. Molkow and W. A. Thompson.
Isle au Haut Bay and Eggemoggin Reach	1-40, 000	1. E. Molkow, W. A. Thompson, and J. J. Young.
Penobscot River and Belfast Bay	1-40, 000	1. E. Molkow and J. J. Young.
Penobscot Bay	1-40, 000	1 and 2. W. A. Thompson. 3. H. M. Knight.
Rockland Harbor	1-20, 000	1. R. F. Bartle. 4. E. H. Sipe, J. G. Thompson, and W. H. Davis.
Isles of Shoals	1-20, 000	4. E. H. Sipe.
Plymouth, Kingston, and Duxbury Harbors	1-40, 000	2. S. Siebert. 3. H. M. Knight. 4. A. Petersen.
New Haven Harbor	1-20, 000	3. R. F. Bartle. 4. J. G. Thompson and W. H. Davis.
Potomac River No. 4	1-40, 000	1. H. M. Knight. 2. A. M. Maedel.

APPENDIX No. 5—Continued.

Title of plates.	Scale.	Engravers.
Harbor-charts—Continued.		
Whale Branch, Inside Passage, between Broad and Coosaw Rivers.	1-40, 000	3 and 4. J. G. Thompson.
Doboy and Altamaha Sound	1-40, 000	3. E. H. Sipe.
Saint George's Reef and Crescent City	1-40, 000	2 and 3. R. F. Bartle. 4. J. G. Thompson and W. H. Knight.
Columbia River No. 2	1-40, 000	2. H. C. Evans. 4. J. G. Thompson.
COMMENCED.		
General coast-chart.		
Pacific Coast No. VIII, from Point Arena to Cape Mendocino.	1-200, 000	1 and 2. H. Lindenkohl.
Coast-charts.		
No. 42, Pamplico Sound (eastern sheet)	1-80, 000	1 and 2. H. C. Evans. 4. F. Courtenay and A. Petersen.
No. 43, Pamplico Sound (middle sheet)	1-80, 000	1 and 2. H. C. Evans. 4. F. Courtenay and A. Petersen.
No. 87, Pensacola entrance to Mobile entrance	1-80, 000	1. A. Sengteller.
Harbor-charts.		
Blue Hill Bay	1-40, 000	1. E. Molkow.
Bar Harbor	1-10, 000	1, 2, 3, and 4. W. H. Knight.
New York entrance (1875 edition)	1-40, 000	4. E. A. Maedel.
Beaufort Harbor, N. C	1-40, 000	1 and 4. E. H. Sipe.

APPENDIX No. 6.

REPORT UPON ELECTROTYPING AND PHOTOGRAPHING, BY DR. A. ZUMBROCK.

It became necessary during the year to replace the old vat, used in the electrotype-room for holding the copper solution, by a new one. The new vat, twenty inches wide, forty-two inches deep and fifty-two inches long, holding about one hundred and ninety gallons, is made of three-inch white-pine boards, tongued and grooved. Both sides were covered with two coats of coal-tar, and just before being put together all of the joints were served with a hot cement of rosin, asphalt, and coal-tar; when finished the same cement was applied boiling hot to all of the joints on the inside.

The first trial of a plate in this new vat was made with the copper solution which had always worked well in the old one. It was found that the copper was deposited in regular vertical streaks or ridges, most of the ridges running from top to bottom of the plate, others stopping short at different heights, as though a viscid fluid had run down the plate. Some of the ridges were one-eighth of an inch wide, and there were often as many as five in the breadth of one inch. Weakening and strengthening the copper solution, filtering and boiling it, had no effect upon this unusual action; neither had a stronger or weaker electric current. When the paper, through which some of the copper solution had been filtered, was digested with alcohol, the alcohol became brownish, and left, after evaporation, an oily fluid of an empyreumatic odor. Ether shaken with the solution, left, after evaporation, a similar fluid. A new copper solution acted in the same way.

The effect was undoubtedly due to the fact that the copper solution had dissolved some of the cement. A box of thin sheet-copper was then made to fit loosely in the vat, the narrow space between this copper case and the vat was filled with melted paraffine, and with this arrangement the solution has worked very well.

Last year Congress made an appropriation for the engraving and printing of the plate of the Centennial stock-certificate by the Engraving and Printing Bureau of the Treasury Department. In order to print the number of impressions required for one million shares of stock, the Treasury Department requested the Coast Survey Office to have made twenty electrotype copies of the original plate. This plate is twenty-two by twenty-six inches, weighing about fifteen pounds.

To make so large a number of plates in addition to our own work it became necessary to put up new batteries. The number of good sharp impressions which can be taken from a copper-plate being limited to about twelve hundred, it is evident that the required number of impressions could not be taken from twenty copper-plates; it was therefore desired to have the plates "steel-faced"—that is, covered with a thin layer of electrotype iron. After a number of experiments I succeeded with a solution recommended many years ago by Professor Böttger. I used a strong solution of one part of protosulphate of iron and one-half part of chloride of ammonium; a plate of the best boiler-iron was employed as an anode and a weak electric current. In spite of the most careful cleaning of the copper-plate there were always some spots which would not take the iron unless the plate was removed from the solution and cleaned very frequently. If during the deposition of the iron there should be the slightest evolution of hydrogen on the copper-plate, the plate would be spoiled, for each little bubble of gas will cause a minute hole or pit which takes the ink and spoils the impression. This evolution of hydrogen must be prevented by the proper proportion between the strength of the solution, size of the plate, and battery-power. As soon as the proper amount of iron is deposited, the plate must be washed and dried rapidly or it would immediately rust. This is best done by pouring hot water over the well-washed plate and drying it by means of a soft cloth while yet hot; it should then be covered by a film of paraffine.

The electrotype iron is quite hard and becomes a permanent magnet, the end of the plate which is lowest in the process becoming a north-pole. The amount of iron deposited I found to be

2.56 milligrams for each square centimeter, equal to a thickness of 0.033 millimeter, or about one-seven-hundredth part of an inch. The iron deposit can be dissolved from the copper by acids with the greatest ease and without injuring the engraving in the slightest degree. After ten thousand good sharp impressions had been taken from one of these plates, the iron deposit seemed as perfect as ever. But should it at any time show signs of wearing off, the iron could be removed and a new deposit made upon the same copper-plate; and as this process could be repeated over and over again, there is, by the method of "steel-facing," practically no limit to the number of impressions which can be taken from one copper-plate.

In the operations for photographing, several improvements have been made in the large camera and its stand; I also constructed an apparatus for measuring the photographic image on the wet plate. In consequence of these improvements, photographic reductions of charts are now made with much more expedition and accuracy than heretofore. The collodion, varnish, and some of the other chemicals used in photographing and electrotyping were made by me.

During the autumn of 1874 some experiments were made in transferring drawings upon a copper-plate by photographing and etching by perchloride of iron. A polished copper-plate was silvered, exposed to vapors of iodine in the dark, exposed to the light under an inverted negative, fixed by hyposulphite of soda and varnished with a tough transparent varnish. The drawing was then engraved with a dry point and etched with perchloride of iron. In the opinion of experts this process is quite a success.

APPENDIX No. 7.

List of original topographic sheets, geographically arranged, registered in the archives of the United States Coast Survey from January, 1834, to July, 1875. (Nos. 1 to 1378, inclusive.)

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Letite Passage and vicinity	New Brunswick	1-10,000	1865	W. H. Dennis	1007
Part of Bay of Fundy	Maine and New Brunswick.	1-10,000	1861-'2-'3	......do	981
Saint Croix River (Calais and Saint Stephens)	...do	1-10,000	1869	......do	1150
West Quoddy Bay	Maine	1-10,000	1861-'2-'3	......do	980
Eastport and vicinity	...do	1-10,000	1861-'2-'3	......do	979
Moose-a-bec Reach (upper sheet)	...do	1-10,000	1870	J. W. Donn	1172
Moose-a-bec Reach (middle sheet)	...do	1-10,000	1870	......do	1171
Moose-a-bec Reach (lower sheet)	...do	1-10,000	1870	......do	1173
Gouldsborough Bay	...do	1-10,000	1865	C. Rockwell	1039
Winter Harbor to Gouldsborough Bay	...do	1-10,000	1865	......do	1040
Mount Desert Island, Somes Sound and Carter's Mountain	...do	1-10,000	1871	J. W. Donn	1243
Mount Desert Island, southwest part	...do	1-10,000	1872	......do	1281
Mount Desert Island, western part	...do	1-10,000	1872	......do	1282
Mount Desert Island, northeastern part (2 sheets)	...do	1-10,000	1873	......do	1334*a b*
Mount Desert Island, Egg Rock	...do	1-5,500	1874	......do	1334*c*
Mount Desert Island, Hull's Cove to Pretty March	...do	1-10,000	1874	......do	1364
Mount Desert Island, Sand's Point to High Head	...do	1-10,000	1874	......do	1365
Frenchman's Bay, east side from Waukeag Neck to Winter Harbor, including Stave, Jordan, Iron Bound, and Calf Islands.	...do	1-10,000	1862	C. Rockwell	891
Islands south of Mount Desert	...do	1-10,000	1871	J. W. Donn	1245
Great and Little Cranberry Islands and Sutton Island	...do	1-10,000	1871	......do	1244
North Haven Island, including ledges, and island north of Main and Little Thoroughfares.	...do	1-10,000	1867	F. W. Dorr	1072
Baker's Island	...do	1-2,500	1854	W. E. Greenwell	463
Belfast and Searsport	...do	1-10,000	1871-'2	C. T. Iardella	1272
Camden and Rockport Harbors, Penobscot Bay	...do	1-10,000	1863	F. W. Dorr	930
North part of Vinal Island, with Stimpson's, Calderwood's, and Babbage Islands.	...do	1-10,000	1868	......do	1075
North Isleborough, Penobscot Bay	...do	1-10,000	1871	A. W. Longfellow	1257
South Isleborough, Penobscot Bay	...do	1-10,000	1871	......do	1256
Eggemoggin Reach, east part (2 sheets)	...do	1-10,000	1872	C. Hosmer	1286*a b*
Deer Isle, Isle au Haut Bay	...do	1-10,000	1872	W. H. Dennis	1297
Isle au Haut and adjoining islands	...do	1-10,000	1872	J. N. McClintock	1311
Islands in Penobscot Bay, north and south	...do	1-10,000	1873-'4	......do	1350*a b*
Islands in Jericho Bay	...do	1-10,000	1874	......do	1351
Bugaduce River, from mouth to bridge	...do	1-10,000	1874	H. Adams	1372
Castine and part of Penobscot	...do	1-10,000	1874	A. W. Longfellow	1377
Cape Rosier, a part of Brookeville	...do	1-10,000	1872-'3	......do	1330
Penobscot Bay, north shore from Sear's Island to Sandy Point.	...do	1-10,000	1872-'3	C. T. Iardella	1329
Penobscot Bay, island south of Isleborough	...do	1-10,000	1870	......do	1167
Penobscot Bay, west shore from Meganticook to Knight's Point.	...do	1-10,000	1871	F. W. Dorr	1233
Penobscot Bay, west shore from Knight's Point to Little River.	...do	1-10,000	1872	......do	1288
Fox Islands, western part of	...do	1-10,000	1868	......do	1093
Fox Islands, southeastern part of	...do	1-10,000	1870	H. M. De Wees	1157*a*
Fox Islands, southeast part of, and Smith, Saddle-back, and Brimstone Islands.	...do	1-10,000	1870	......do	1157*b*
Rockland Harbor and Rockland, Penobscot Bay (rejected).	...do	1-10,000	1861	C. Ferguson	843

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Rockland Harbor and vicinity	Maine	1-10,000	1870	W. H. Dennis	1160
South Thomaston, Weskeag River, &c., Penobscot Bay (rejected).	...do	1-10,000	1861	C. Ferguson	844
The western entrance to Penobscot Bay, including Saint George's Island, Mohegan, and Matinicus.	...do	1-20,000	1864	F. W. Dorr	960
Seal, Tennant's, and Mosquito Harbor, Penobscot Bay (rejected).	...do	1-10,000	1862	C. Ferguson	904
Seal, Tennant's, and Mosquito Harbors, Penobscot Bay	...do	1-10,000	1868	W. H. Dennis	1081
The Matinicus group of islands	...do	1-20,000	1864	F. W. Dorr	938
The Green Islands, off the mouth of Penobscot Bay	...do	1-20,000	1864	......do	959
Muscle Ridge Islands, Penobscot Bay (rejected). (See 1287.)	...do	1-10,000	1862	C. Ferguson	877
Muscle Ridge Islands, Penobscot Bay	...do	1-10,000	1871	W. H. Dennis	1287
Friendship, approaches to Medomak River	...do	1-10,000	1867	Charles Hosmer	1058
Penobscot River from Indian Point to Parker's Point	...do	1-10,000	1873	F. W. Dorr	1309
Penobscot River, Indian Point to Sandy Point and eastern shore.	...do	1-10,000	1873-'4	C. T. Iardella	1357*a b*
Weskeag River and vicinity	...do	1-10,000	1869	W. H. Dennis	1151
Saint George's River from Narrows to Thomaston (rejected).	...do	1-10,000	1863	C. Ferguson	915
Saint George's River from entrance to Narrows (rejected).	...do	1-10,000	1864	C. Ferguson	957
Saint George's River entrance	...do	1-10,000	1869	F. W. Dorr	1117
Saint George's River	...do	1-10,000	1868	Charles Hosmer	1116
Muscongus Bay, islands and ledges	...do	1-10,000	1865	F. W. Dorr	1001
Muscongus Bay, southern part	...do	1-10,000	1865	.....do	1002
Muscongus Bay from Round Pond to Hocamoc	...do	1-10,000	1866	C. Rockwell	1028
Medomak River	...do	1-10,000	1867-'8	Charles Hosmer	1076
Medomak River, upper part	...do	1-10,000	1865	C. Ferguson	984
Pemmaquid Neck, including John's Bay and Pemmaquid River.	...do	1-10,000	1863	F. W. Dorr	1032
Pemmaquid Point, including New Harbor and west shore Muscongus Bay.	...do	1-10,000	1866	......do	1033
Damariscotta River (upper part)	...do	1-10,000	1865	S. A. Gilbert	994
Damariscotta River (lower part)	...do	1-10,000	1865	.....do	995
Linekin's Bay and Islands at mouth of Damariscotta River.	...do	1-10,000	1865	F. W. Dorr	1000
Merry Meeting Bay, including Androscoggin, Muddy, and Cathance Rivers.	...do	1-10,000	1871	C. H. Boyd	1214
Booth Bay Harbor and vicinity	...do	1-10,000	1864	P. C. F. West	961
Sheepscot River	...do	1-10,000	1864	R. E. McMath	954
Part of Sheepscot River and vicinity	...do	1-10,000	1859	W. H. Dennis	845
Sheepscot, Back, and Ovenmouth Rivers	...do	1-10,000	1864	R. E. McMath	953
Sheepscot and Back Rivers	...do	1-10,000	1860	H. Adams, C. Ferguson	801
Back River and Monteeag Bay	...do	1-10,000	1860-'1	C. Ferguson, H. Adams	802
Hoackomoak Bay and islands south of Phipps' Point, Back River.	...do	1-10,000	1861	H. Adams, O. Henricks	842
Kennebec River entrance and Cape Small Point	...do	1-10,000	1856	Hull Adams	587
Cape Small Point and adjacent islands	...do	1-10,000	1854-'7	S. A. Gilbert, C. T. Iardella	465
Kennebec River approaches	...do	1-10,000	1856	Hull Adams	583
Kennebec River (from Indian Point to Cox's Head)	...do	1-10,000	1857	W. S. Gilbert	666
Georgetown Island and vicinity	...do	1-10,000	1862	C. T. Iardella	889
Kennebec River, from Bath to Jones' Eddy	...do	1-10,000	1857	W. S. Gilbert	667
Kennebec River, vicinity of Bath	...do.	1-10,000	1858-'9-'60	R. M. Bache	728
Peninsula formed by confluence of Kennebec and Androscoggin Rivers.	...do	1-10,000	1864	.....do	967
Westport and Arrows'c Islands (part of)	...do	1-10,000	1865	E. Hergesheimer	982
Kennebec River (head of)	...do	1-10,000	1859-'65	R. M. Bache	1061
Kennebec River (from Abagadasset Point to Richmond)	...do	1-10,000	1869	C. H. Boyd	1115
Kennebec River (from Richmond to Gardner)	...do	1-10,000	1870	.....do	1138
Mouth of New Meadow River	...do	1-10,000	1857	C. T. Iardella	655
New Meadow River from Forster's Point to New Meadow Bridge.	...do	1-10,000	1866	J. W. Donn	1021

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Ragged Island and adjacent islands near Cape Small Point.	Maine	1-10, 000	1854-'57	S. A. Gilbert, C. T. Iardella	466
Maquoit and Middle Bays, with adjacent shores of Freeport, Brunswick, and Harpswell Neck.	...do	1-10, 000	1863	A. W. Longfellow	923
Yarmouth and Freeport	...do	1-10, 000	1861-'2	...do	918
Part of Harpswell Neck, with the adjacent islands in Casco Bay.	...do	1-10, 000	1860-'1	...do	847
Casco Bay (outer islands)	...do	1-10, 000	1856-'58	...do	757
Casco Bay (The Green Islands)	...do	1-10, 000	1856	...do	756
Great Jeboig, Cousins, and Little John's Islands, with smaller islands and part of the main shore.	...do	1-10, 000	1864	...do	919*a*
Casco Bay	...do	1-10, 000	1873	...do	919*b*
Presumpscot River, mouth of, and islands in Casco Bay	...do	1-10, 000	1855-'59	...do	755
Casco Bay (from Middle Bay to New Meadow River, including north end of Sebaskahegan Island).	...do	1-10, 000	1867-'69	...do	1129
Casco Bay (Sebaskahegan and Orr's Islands)	...do	1-10, 000	1865	...do	1012
Casco Bay (sketch of Half-Way Rock)	...do	1-2, 000	1867	C. H. Boyd	1056
Portland Harbor and environs	...do	1-10, 000	1854-'58	A. W. Longfellow	735
Portland Harbor (reconnaissance of the environs and approaches to).	...do	1-20, 000	1862	F. W. Dorr	878
Portland Harbor (wharf and shore-line)	...do	1-5, 000	1867	A. W. Longfellow, H. W. Bache.	1111
Portland City and Harbor (special survey, sheet No. 1)	...do	1-1, 200	1868-'9	A. Lindenkohl	1140*a*
Portland City and Harbor (special survey, sheet No. 2)	...do	1-1, 200	1868-'9	...do	1140*b*
Portland City and Harbor (special survey, sheet No. 3)	...do	1-1, 200	1868-'9	...do	1141*a*
Portland City and Harbor (special survey, sheet No. 4)	...do	1-1, 200	1869	Charles Hosmer	1141*b*
Portland City and Harbor (special survey, sheet No. 5)	...do	1-1, 200	1869	...do	1142*a*
Portland City and Harbor (special survey, sheet No. 6)	...do	1-1, 200	1869	J. W. Donn	1142*b*
Portland City and Harbor (special survey, sheet No. 7)	...do	1-1, 200	1869	...do	1143*a*
Portland City and Harbor (special survey, sheet No. 8)	...do	1-1, 200	1869	Charles Hosmer	1143*b*
Portland City and Harbor (special survey, sheet No. 9)	...do	1-1, 200	1869	J. W. Donn	1144*a*
Portland City and Harbor (special survey, sheet No. 10)	...do	1-1, 240	1869	J. N. McClintock	1144*b*
Part of Cape Elizabeth	...do	1-10, 000	1852	A. W. Longfellow	414
Richmond's Island	...do	1-10, 000	1850	...do	312
Saco Bay, north shore, including Stratton and Bluff Islands and Prout's Neck.	...do	1-10, 000	1859	C. Fendall	759
Mouth of Saco River and Biddeford Pool	...do	1-10, 000	1870	H. Adams	1188
Saco River and towns of Biddeford and Saco	...do	1-10, 000	1871	...do	1225
Goose Fair Creek to Spurwink River	...do	1-10, 000	1871	...do	1224
Fletcher's Neck and vicinity	...do	1-10, 000	1859	C. Fendall	760
Cape Porpoise and vicinity	...do	1-10, 000	1859	...do	761
Kennebunk Port and Cape Porpoise to Hoyt's Neck	...do	1-10, 000	1870	H. Adams	1159
Well's Beach, included in sheet No. 1121	...do	1-10, 000	1867	...do	1057
Coast from Ogunquit, in Wells, to Mousam River	...do	1-10, 000	1869	...do	1121
Cape Neddick and Ogunquit	...do	1-10, 000	1854	A. S. Wadsworth	459
York and Cape Neddick Harbors, with intermediate coast.	...do	1-10, 000	1853	A. W. Longfellow	440
Coast from Kittery to York	...do	1-10, 000	1867	H. Adams	1050
Coast from Boar's Head to Rye Harbor	New Hampshire	1-10, 000	1866	...do	1023
Coast from Rye Harbor to near Portsmouth	...do	1-10, 000	1867	...do	1047
Isles of Shoals	...do	1-10, 000	1859	C. Fendall	762
From Hampton River to East Salisbury	...do	1-10, 000	1855	H. L. Whiting	835
Newburyport and mouth of Merrimac River	Massachusetts	1-10, 000	1852	A. W. Longfellow	355
Rowley River and part of Plum Island to Newburyport	...do	1-10, 000	1854	H. L. Whiting, H. Adams	559
Ipswich, (unfinished)	...do	1-10, 000	....	H. L. Whiting	467
Annisquam Harbor and vicinity, Cape Ann	...do	1-10, 000	1852	H. L. Whiting, R. M. Bache	396
Cape Ann, northern shore, including Essex River	...do	1-10, 000	1855	H. L. Whiting	556
Rockport, extremity of Cape Ann, from Milk Island to Lane's Cove.	...do	1-10, 000	1851	...do	311
Gloucester Harbor and vicinity, Cape Ann	...do	1-10, 000	1851	H. L. Whiting, R. M. Bache	397
South shore of Cape Ann, from Danvers' new mills to Beverly farms.	...do	1-10, 000	1851	H. L. Whiting	304
Salem Harbor, from Beverly farms to Kettle Cove	...do	1-10, 000	1851	...do	340

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Salem Harbor, Manchester (including the city and islands).	Massachusetts	1-10, 000	1851	H. L. Whiting	303
From Saugus River to Marblehead, northwest shore of Massachusetts Bay.	do	1-10, 000	1849-'50	do	305
Nahant Neck and Tinker's Island	do	1-10, 000	1847	do	235
From Point Shirley to Point Pines and Winnessimit Village.	do	1-10, 000	1847	do	234
Governor's Island and Castle Island, Boston Harbor	do	1-5, 000	1846	do	231
Thompson Island, Outer Brewster, and intermediate islands, Boston Harbor.	do	1-10, 000	1847-'9	J. S. Williams, H. L. Whiting.	238
Cities of Boston and Charlestown	do	1-5, 000	1846-'7	H. L. Whiting	229
East and South Boston	do	1-5, 000	1846-'7	do	230
From Neponset to Roxbury (interior)	do	1, 10, 000	1847	do	232
From Roxbury to Malden (interior)	do	1, 10, 000	1847	do	233
From Milton Mills to Hingham, southern shore of Boston Bay.	do	1, 10, 000	1847	J. B. Glück	227
Part of Boston Harbor (including the outer and Brewster Islands.	do	1-5, 000	1860	H. L. Whiting	830
Part of Boston Harbor (including Gallop's, Lovell's, George's, Light-House, and Great Brewster Islands).	do	1-5, 000	1860	do	831
Part of Boston Harbor (including Long and Deer Islands and Point Shirley).	do	1-5, 000	1860	do	833
Part of Boston Harbor (including Thompson's and Spectacle Islands, Moonhead, and Squantum).	do	1-5, 000	1860	do	832
Part of Boston Harbor (Rainsford and Peddock's Island, and Nantasket).	do	1-5, 000	1860	do	829
From Nantasket Hill to Green Hill, Boston Bay	do	1-10, 000	1847	J. S. Williams	237
From World's End Hill to Cohasset Harbor, Boston Bay.	do	1-10, 000	1847	J. B. Glück	228
From Cohasset to Scituate Harbor, eastern shore	do	1-10, 000	1847	H. L. Whiting, S. A. Gilbert	236
North River	do	1, 10, 000	1858	A. M. Harrison	719
North River (sheet 1)	do	1-5, 000	1870	H. L. Whiting	1251a
North River (sheet 2)	do	1-5, 000	1870	do	1251b
Back River and vicinity, near Plymouth	do	1-10, 000	1856-'7	R. M. Bache, A. M. Harrison	612
Kingston to Duxbury Beach	do	1-10, 000	1853-'4	S. A. Gilbert, R. M. Bache	425
Plymouth Harbor and vicinity	do	1-10, 000	1853	S. A. Gilbert	435
Cape Cod Bay, western shore, from Eel River to Ship Pond.	do	1-10, 000	1866	P. C. F. West	1063
Cape Cod Bay, western shore, from Ship Pond to West Sandwich.	do	1-10, 000	1867	do	1062
Cape Cod, part of, from Sandy Neck, near Barnstable, to West Sandwich.	do	1-10, 000	1860-'1	A. M. Harrison	901
Barnstable Harbor and vicinity	do	1-10, 000	1859	do	795
Cape Cod Bay, north shore, from North Dennis to Brewster.	do	1-10, 000	1868	P. C. F. West	1088
Cape Cod Bay, southern shore, from Orleans to Brewster.	do	1-10, 000	1868	H. Adams	1078
Cape Cod Peninsula, from Billingsgate to Pamet River	do	1-10, 000	1848	H. L. Whiting	259
Wellfleet Harbor, Cape Cod Peninsula	do	1-10, 000	1851	J. B. Glück	368
Northern part of Cape Cod and Provincetown Harbor	do	1-10, 000		H. L. Whiting	616
From Higland to Nauset Light	do	1-10, 000	1848	do	260
From Nauset Light to Orleans	do	1-10, 000	1856	C. T. Iardella	579
Cape Cod Bay, eastern shore, from Pleasant Bay to Nauset Harbor.	do	1-10, 000	1868	H. Adams	1077
Cape Cod, southern extremity, including village of Chatham.	do	1-10, 000	1868	H. W. Bache	1085a
Cape Cod, from Pleasant Point to Monomoy Island	do	1-10, 000	1868	C. H. Boyd	1085b
Cape Cod, southern extermity of	do	1-10, 000		J. B. Glück	441
Monomoy Point	do	1-20, 000	1868	P. C. F. West	1090
Monomoy Island	do	1-20, 000	1853-'56	S. A. Gilbert, C. T. Iardella	424
From Bass River eastward	do	1-10, 000		J. B. Glück	402
From Bass River to Hyannis, including West Yarmouth and South Dennis.	do	1-10, 000	1855	H. L. Whiting, J. A. Sullivan.	553

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Part of South Yarmouth, Barnstable County	Massachusetts	1-10, 000	1852	A. W. Longfellow	356
From West Yarmouth to Hyannis Point	...do	1-10, 000	1846	W. M. Boyce	290
From Hyannis Point to Succonnesset	...do	1-10, 000	1846	.....do	318
From Succonnesset Point to Falmouth Spire	...do	1-10, 000	1846	.....do	289
Eastern part of Nantucket, Great Point to Siasconsett	...do	1-10, 000	....	H. L. Whiting, W. E. Greenwell.	206
Western part of Nantucket, including Tuckannc and Muskeget Islands.	...do	1-10, 000	1846	H. L. Whiting	205
Martha's Vineyard, eastern part, from Cape Poge to East Chop.	...do	1-10, 000	1846	.....do	204
Northern shore of Martha's Vineyard, from East Chop to Menemsha Bight.	...do	1-10, 000	1846	.....do	203
Southern shore of Martha's Vineyard, from Sampson's Hill to East Edgartown Harbor.	...do	1, 10, 000	1846-'56	.....do	202
Gay Head, part of Martha's Vineyard, and No Man's Land.	...do	1-10, 000	1845-'53	W. M. Boyce, H. L. Whiting.	362
Cuttyhunk Island, with Sow and Pig Shoal	...do	1-5, 000	1853	H. L. Whiting	437
Elizabeth Islands	...do	1-10, 000	1845	W. M. Boyce	192
From Falmouth to Back River, eastern shore of Buzzard's Bay.	...do	1-10, 000	1845	.....do	191
From Great Hill Neck to Sconticut Neck, western shore of Buzzard's Bay.	...do	1-10, 000	1845	H. L. Whiting	196
From Back River to Great Hill Neck, northern part of Buzzard's Bay.	...do	1-10, 000	1845	.....do	195
From Sconticut Neck to Clark's Neck, including New Bedford.	...do	1-10, 000	1844	.....do	194
From Clark's Point to Mishaum (missing)	...do	1-10, 000	1844	.....do	193
From Mishaum Point to Saughkonnet Point	...do	1-10, 000	1844	W. M. Boyce	183
Taunton River, part of	...do	1-5, 000	1874	A. M. Harrison	1373
Fall River, part of. (See No. 1053)	...do	1-10, 000	1861	.....do	885
City of Fall River and vicinity	...do	1-10, 000	1867	.....do	1053
Mount Hope Bay, including parts of Taunton, Lee, and Cole Rivers. (See No. 1024.)	Massachusetts and Rhode Island.	1-10, 000	1861	A. M. Harrison, P. C. F. West.	886
Saughkonnett (or Seaconnet) River, from Church's Point northward.	Rhode Island	1-10, 000	1844	H. L. Whiting	180
Saughkonnet Point	...do	1-10, 000	1870	Charles Hosmer	1161
Saughkonnet River, eastern part	...do	1-10, 000	1870	.....do	1156
Mount Hope Bay, part of	...do	1-10, 000	1861-'65	A. M. Harrison	884
Mount Hope Bay, northern part	...do	1-10, 000	1865	.....do	1024
Warren	...do	1-10, 000	1869	.....do	1120
Bristol Neck. (See 888)	...do	1-10, 000	1864	A. M. Harrison, C. Hosmer	936
Mount Hope and Bristol Bays, part of. (See 956)	...do	1-10, 000	1862	A. M. Harrison	888
Part of shore-line of Narragansett Bay and Providence River.	...do	1-10, 000	1863	.....do	913
Shore-line of part of Providence River	...do	1-10, 000	1863	.....do	914
City of Providence, wharf-line	...do	1-5, 000	1867	.....do	1041
Seekonk River	...do	1-10, 000	1865	.....do	978
Part of the western shore of Narragansett Bay, including Greenwich Bay and Hope Island.	...do	1-10, 000	1863	.....do	912
Town of East Greenwich and vicinity	...do	1-10, 000	1868	.....do	1079
Prudence Island, Narragansett Bay	...do	1-10, 000	1865	.....do	1054
Prudence Island, Narragansett Bay. (See 1054)	...do	1-10, 000	1862	.....do	887
Island of Rhode Island, northern part	...do	1-10, 000	1870	.....do	1162
Shore-line of the western side of the western passage of Narragansett Bay.	...do	1-10, 000	1863-'69	.....do	911
Conanicut, Dutch, and Gould Islands	...do	1-10, 000	1869	.....do	1119
Conanicut Island, part of Narragansett Bay. (See 1119)	...do	1-10, 000	1861	.....do	898
Coast of Rhode Island, from Cross Mills eastward	...do	1-10, 000	1872	.....do	1271
Coast of Rhode Island, from Cross Mills to West Pond	...do	1-10, 000	1873	.....do	1312
Newport and vicinity	...do	1-10, 000	1870-'1	.....do	1194
Narragansett Bay, including Coaster's Island Harbor and adjacent shores.	...do	1-5, 000	1862	H. L. Whiting	869

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Entrance to Narragansett Bay, Eastern Rock to Beaver Tail.	Rhode Island	1-10,000	1844	W. M. Boyce	182
Island of Rhode Island, from Black Point to Easton Point.	....do	1-10,000	1870	H. G. Ogden	1163
Part of the west shore of Rhode Island, from Coddington Cove northward.	....do	1, 10,000	1862	A. M. Harrison	896
Part of the west shore of Rhode Island, from Bristol Bay southward. (See 1162.)	....do	1-10,000	1861	......do	897
Narragansett Pier to South Ferry	....do	1-10,000	1869	......do	1118
From McSparran Hill to Point Judith	....do	1-10,000	1839	J. J. S. Hassler	92
From McSparran Hill to Tiff's Hill, (interior)	....do	1-10,000	....	......do	93
From Point Judith to Noyes' Point	....do	1-10,000	1839	......do	91
From Tiff's Hill westward, (interior)	....do	1-20,000	1839	......do	94
Point Judith and vicinity	....do	1-10,000	1871	A. M. Harrison	1226
Kingston, from Fairbanks's Cut northward	....do	1-20,000	1840	J. J. S. Hassler	128
Joshua Champlin Fairbanks's Cut to Sand Hill southward.	....do	1-20,000	1840	......do	129
Block Island	....do	1-10,000	1839	......do	90
From Big Hill to North Stonington, (interior)	....do	1-10,000	1840	F. H. Gerdes	126
Milltown and interior, from North Stonington to Niantic Village.	Connecticut	1-10,000	1840	......do	123
North Stonington and interior, from Eel's Hill to Quaquotogue.	....do	1-10,000	1840	......do	124
From Fort Hill to Mystic River	....do	1-10,000	1838	Charles Renard	65
From Mystic Bridge to Noyes River on Fisher's Island	....do	1-10,000	1839	F. H. Gerdes	88
From Lantern Hill to Thames River	....do	1-10,000	1839	......do	89
From Fort Hill to Black Point, including Niantic Bay	....do	1-10,000	1838	Charles Renard	64
New London Harbor, eastern shore of Thames River	....do	1-10,000	1846	J. B. Glück	85
Thames River, western shore	....do	1-10,000	1846	......do	84
Thames River, (continued)	....do	1-10,000	1841	F. H. Gerdes	87
Thames River, from New London to Mohican	....do	1-10,000	1839	......do	86
Thames River, (Thomasville and city of Norwich)	....do	1-10,000	1874	H. G. Ogden	1359 a b
Navy-yard near New London	....do	1-1,200	1869	......do	1107
Between Niantic and Thames Rivers, (interior)	....do	1-10,000	1839	F. H. Gerdes	83
From Niantic River to Lynn City, (interior)	....do	1-20,000	1838	Charles Preuss	78
From Lynn City to Westbrook, (interior)	....do	1-20,000	1838	J. J. S. Hassler	79
From Black Point to Cornfield Point, mouth of Connecticut River.	....do	1-10,000	1838	B. F. Sands	81
Mouth of Connecticut River	....do	1-10,000	1850	H. L. Whiting	297
From Cornfield Point to Hammonasset, Saybrook, and Clinton.	....do	1-10,000	1838	J. J. S. Hassler	80
From Essex to North Killingworth, including Clinton	....do	1-10,000	1840	T. W. Werner	130
From North Killingworth to North Hill, East Haven, and Hammonasset.	....do	1-10,000	1839	......do	105
From Hammonasset Point to New Haven	....do	1-10,000	1838	W. M. Boyce	82
From New Haven to Fairhaven, Catron's Rock, and Whitneyville.	....do	1-10,000	1838	John Farley	76
New Haven Harbor	....do	1-10,000	1872	R. M. Bache	1296
From West Haven to Black Rock, (sound shore)	....do	1-10,000	1837	C. M. Eakin	22
From Cheshire and Mt. Carmel to Tashua and Mervin	....do	1-20,000	1839-'40	T. W. Werner	106
From Tashua westward, Chestnut Hill to New Canaan	....do	1-10,000	1839	T. A. M. Craven	107
From Centre Redding to Wilton, east of Ridgefield	....do	1-20,000	1840	H. L. Dickens	131
From Bridgeport to Saugatuck, Sherwood, and Gorham	....do	1-10,000	1838	T. A. M. Crav.n	51
From Black Rock to Norroton	....do	1-10,000	1835	C. M. Eakin	19
From Saugatuck and Westbrook to Darien, (interior)	....do	1-10,000	1838	T. A. M. Craven	50
Seafield and vicinity, (interior)	....do	1-10,000	1839	......do	108
From Round Hill to New Castle, (interior)	....do	1-10,000	1839	......do	109
From Darien to Glenville and Horse Neck	....do	1-10,000	1838	......do	49
From Norroton Point to Delancy's Point, including Rye	....do	1-10,000	1836	C. M. Eakin	20
Lake Champlain, from White's Landing to Apple Tree Point.	Vermont	1-10,000	1870	F. W. Dorr	1181 a
Lake Champlain, including city of Burlington	....do	1-10,000	1872	H. G. Ogden	1181 b

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Lake Champlain, from Apple Tree Point to Hog Back Island.	Vermont	1-10,000	1870	F. W. Dorr	1182
Lake Champlain, from Trembleau Point to Port Jackson	...do	1-10,000	1870	......do	1183
Lake Champlain, from Trembleau Point to Ligonier Point.	...do	1-10,000	1870	F. W. Dorr and Charles Hosmer.	1185
Lake Champlain, vicinity of Plattsburg	New York	1-10,000	1870	Charles Hosmer	1184 *a*
Lake Champlain, vicinity of Plattsburg	...do	1-10,000	1873	H. G. Ogden	1184 *b*
Lake Champlain, vicinity of Plattsburg	Vermont	1-10,000	1870	Charles Hosmer	1186
Lake Champlain, vicinity of Mallet's Bay	...do	1-10,000	1871	......do	1205
Lake Champlain shore-line surveys	...do	1-10,000	1871	......do	1206
Lake Champlain shore-line surveys	...do	1-10,000	1871	......do	1207
Lake Champlain shore-line surveys	...do	1-10,000	1871	......do	1208
Lake Champlain shore-line surveys	...do	1-10,000	1871	......do	1209
Lake Champlain, from Cumberland Head Point to Point-au-Roche.	New York	1-10,000	1871	H. G. Ogden	1217
Lake Champlain, the Gut and Point-au-Roche	...do	1-10,000	1871	......do	1218
Lake Champlain, from Point-au-Roche to Long Point	...do	1-10,000	1871	......do	1219
Lake Champlain, La Motte and Alburgh Passages	...do	1-10,000	1871	......do	1220
Lake Champlain, from Isle La Motte to boundary-line	...do	1-10,000	1871	......do	1221
Lake Champlain, part of Missisquoi Bay	Vermont	1-10,000	1871	......do	1222
Lake Champlain, Missisquoi Bay south of boundary-line	...do	1-10,000	1871	......do	1223
Lake Champlain, part next to Jones's Point subsheet	Vermont and New York.	1-10,000	1873	......do	1319 *a b*
Lake Champlain, Bluff Point to Point Kemp	...do	1-10,000	1873	A. Braid	1320
Lake Champlain, Fort Ticonderoga	...do	1-2,500	1874	......do	1360 *a*
Lake Champlain, Plumes Point to Kirby	...do	1, 10, 000	1874	......do	1360 *b*
Lake Champlain, Kirby to Chipman's Point	...do	....	1874	......do	1360 *c*
Lake Champlain, Chipman's Point to Light-House No. 10, Light-House No. 10 to Whitehall.	...do	1-10,000	1874	......do	1361 *ab*
Lake Champlain, Sexton's Point to Hill's Point, (Four Brothers.)	...do	1-10,000	1874	C. T. Iardella	1366 *a b*
Lake Champlain, from Essex to Split Rock, Split Rock to Dickerson's Point.	...do	1-10,000	1874	......do	1367 *a b*
Lake Champlain, Dickerson's Point to Potash Point, Elm Point to Crown Point.	...do	1-10,000	1874	......do	1368 *a b*
Fisher's Island and others adjacent, Long Island Sound	New York	1-10,000	1838	F. H. Gerdes	57
Plum Island and Gull Island, Long Island Sound	...do	1-10,000	1838	......do	56
Gardiner's Island, Long Island Sound	...do	1-10,000	1838	T. A. Jenkins	75
Sag Harbor, Gardiner's Bay, and Three Mile Harbor	...do	1-10,000	1838-'46	T. A. Jenkins and J. B. Glück.	72
Cooper's Hill and Oyster Pond Point	...do	1-10,000	1838	F. H. Gerdes	55
Shelter Island, Peconic Bay, Long Island Sound	...do	1-10,000	1838	T. A. Jenkins	69
North Peconic Bay, from Catchoque to Halleck's Point	...do	1-10,000	1838	......do	68
Peconic Bay, from Noyack to Sag Harbor	...do	1-10,000	1838	......do	71
Peconic Bay, Riverhead to Little Hog Neck	...do	1-10,000	1838	......do	67
Peconic Bay, Good Ground to Noyack	...do	1-10,000	1838	......do	70
Old Landing, Cooper's Hill, and Cypress Points	...do	1-10,000	1838	F. H. Gerdes	54
Friar's Head, River Head, and Old Landing	...do	1, 10, 000	1838	......do	53
Smith's Point to Good Ground and Inlet West	...do	1-10,000	1838	Charles Renard	58
From Ruland's to Riverhead, (interior)	...do	1-20,000	1838	H. L. Dickens	77
Drowned Meadow Harbor, Mount Misery, and Friar's Head.	...do	1-10,000	1838	F. H. Gerdes	52
Setauket City and Drowned Meadow, Old Field Point and Mount Misery.	...do	1-10,000	1837	......do	32
From Stony Brook to Drowned Meadow, (interior)	...do	1-20,000	1837	Charles Preuss	43
From Old Field and Setauket to Stony Brook	...do	1-10,000	1837	F. H. Gerdes	31
From Smithtown to Stony Brook, (interior)	...do	1-10,000	1837	......do	42
From West Hills to Ruland's	...do	1-20,000	1837	H. L. Dickens	45
West Hills and vicinity, (interior)	...do	1-10,000	1836	......do	44
Nissaquaque River, Smithtown, and Stony Brook	...do	1-10,000	1837	F. H. Gerdes	30
Red Hook, Bread and Cheese Hollow, and Smithtown, (interior.)	...do	1-10,000	1837	Charles Preuss	41
Eaton's Neck to Smithtown, (interior)	...do	1-10,000	1837	F. H. Gerdes	29

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
From North Port to Red Hook (interior)	New York	1-10,000	1837	Charles Preuss	40
Cow Harbor, North Port, and Eaton's Neck	...do	1-10,000	1837	F. H. Gerdes	28
Lloyd's Neck to East Neck and Lloyd's Harbor	...do	1-10,000	1836	......do	23
Huntington Bay	...do	1-10,000	1837	.....do	21
Oyster Bay, Cold Spring, and Hog Island	... do	1-10,000	1837	......do	25
Glencove to Oyster Bay (interior)	...do	1-10,000	1838	Charles Preuss	39
From Cold Spring to Glencove	...do	1-20,000	1838	T. A. Jenkins	66
From Hog Island, Matinicock Point, and Red Spring	... do	1-10,000	1837	F. H. Gerdes	26
Matinicock and Hempstead Harbor	...do	1-10,000	1837	.....do	27
Cow Neck and Manhassit	...do	1-10,000	1837	T. W. Werner	34
From Great Neck to Bowen Station	...do	1-10,000	1837-'50	T. W. Werner and H. L. Whiting.	33
Hewlett's Cove, Wilkins' Point, and Great Bay	...do	1-10,000	1837	Charles Renard	14
Rye Point, Delaney's Point, and Rodman's Neck	...do	1-10,000	1837	C. M. Eakin	21
From Horse Neck to Rye	...do	1-10,000	1838	T. A. M. Craven	48
From Hewlett's Cove to Brooklyn	...do	1-10,000	1837	Charles Renard	13
Throg's Neck to Rodman's Point	...do	1-10,000	1837	W. M. Boyce	46
Throg's Neck to Harlem River	...do	1-10,000	1857-'59	F. W. Dorr	604
Harlem River, east side, from High Bridge to King's Bridge.	...do	1-10,000	1859	C. Rockwell	775
Harlem River and Throgs Neck	...do	1-10,000	1837	Charles Renard	15
From Throg's Neck to Ward's Island	...do	1-10,000	1855	F. H. Gerdes	488
From Little Neck Bay to Flushing Bay	...do	1-10,000	1858	C. Rockwell	605
From Flushing Bay to Hunter's Point	...do	1-10,000	1858	H. L. Whiting	808
Hell Gate and vicinity	...do	1-5,000	1848	......do	258
From Hell Gate to Brooklyn	...do	1-10,000	1855	F. H. Gerdes	483
Ward's, Randall's, N. and S. Brothers, and Recker's Islands.	...do	1-5,000	1857	H. L. Whiting	675
Part of Brooklyn, including Williamsburg and Green Point.	...do	1-10,000	1859	F. W. Dorr	789
Reconnaissance of Brooklyn, Williamsburg, and Green Point.	...do	1-10,000	1863	F. H. Gerdes	917
New York, Brooklyn, and vicinity	...do	1-10,000	1855-'57	A. Boschke	608
Long Island (interior) between Brooklyn, Flushing, and Jamaica.	...do	1-10,000	1862	H. L. Whiting	924
From Brooklyn to Jamaica	...do	1-20,000	1837	T. A. Jenkins	36
From Brooklyn to Fort Hamilton and Gowanus Island	...do	1-10,000	1837	Charles Renard	12
Vicinity of Gowanus Bay	...do	1-10,000	1856	S. A. Gilbert	599
Vicinity of Gowanus Bay	...do	1-10,000	1856	.....do	598
Gowanus Bay and vicinity	...do	1-10,000	1856	......do	597
From Gowanus Bay to Bath	...do	1-10,000	1855	......do	487
From Fort Hamilton to Coney Island	...do	1-10,000	1835	Charles Renard	5
Coney Island and Dead Horse Inlet	...do	1-10,000	1855-'56	S. A. Gilbert	586
From Coney Island to Rockaway Pavilion	...do	1-20,000	1835	Charles Renard	4
Barren Island, Rockaway Beach	...do	1-20,000	....	S. A. Gilbert	535
Part of Far Rockaway, Long Island	...do	1-9,633	1860	F. W. Dorr	798
From Newlet's to Jamaica and Hicksville	...do	1-20,000	1837	T. A. Jenkins	38
Hicksville and Jamaica, Brushville and Miltham	...do	1-20,000	1837	.....do	37
From Babylon to Fire Island and Rockaway	...do	1-20,000	1835	Charles Renard	3
West end of Fire Island Beach, vicinity of Bay Shore and Islip.	...do	1-10,000	1873	C. Hosmer	1314
Fire Island Beach (a)	...do	1-10,000	1873-'74	.....do	1375 a b
Fire Island Beach (b)	...do	1-10,000	1874	.....do	....
From Babylon to Patchoque and George's Neck	...do	1-10,000	1834	Charles Renard	1
West end of Fire Island to Watch Hill (copy)	...do	1-10,000	1834	......do	479
From Patchoque to Smith's Point	...do	1-10,000	1835	......do	2
Islip and Blue Point; Vicinity of Patchoque	...do	1-10,000	1874	C. Hosmer	1374 a b
Southampton, interior of Long Island	...do	1-10,000	1838	T. A. Jenkins	73
From Good Ground to East Hampton (southern shore)	...do	1-10,000	1838	Charles Renard	59
Bridge Hampton to Acabomock and East Hampton	...do	1-10,000	1838-'46	T.A.JenkinsandJ.B.Glück	74
Neapeague to East Hampton	...do	1-10,000	1838	Charles Renard	60
Neapeague Bay, vicinity of Amagansett, Long Island	...do	1-10,000	1845	W. M. Boyce	61
Long Island, from Montauk Point to Neapeague Bay	...do	1-10,000	1838	B. F. Sands, C. Renard	62

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Staten Island	New York	1-10, 000	1835-'36	Charles Renard	9
Tompkinsville, Staten Island. (See No. 9)	...do	1-5, 000	1835	......do	6
From New Brighton to Great Kills, Staten Island	...do	1-10, 000	1855	A. S. Wadsworth	490
Staten Island, from New Brighton to Fresh Kills	...do	1-10, 000	1856	H. L. Whiting	816
Raritan Bay, from Great Kills to Ward's Point	...do	1-10, 000	1855	A. S. Wadsworth	532
Staten Island, from Ward's Point to Great Kills	...do	1-10, 000	1856	H. L. Whiting	680 *a b*
Northwestern position of Staten Island and Bergen Point	...do	1-10, 000	1857	......do	751
Governor's, Ellis's, and Bedloe's Islands	...do	1-5, 000	1857	John Mechan	677
Bedloe's and Ellis's Islands, New York Harbor	...do	1-10, 000	1855	F. H. Gerdes	543
New York City and Manhattan Island	...do	1-10, 000	1854-'55	......do	475
Manhattan Island, Eastern part of New York City to West Farms.	...do	1-10, 000	1837	Charles Renard	16
Manhattan Island, from Macomb's Dam to Spuyten Duyvel Creek, and tracing.	...do	1-10, 000	1857	John Mechan	658
From Communipaw to Palmipaw	...do	1-10, 000	1857	......do	662
Hudson River, from Jersey City to Guttenburg	...do	1-10, 000	1855	F. H. Gerdes	484
Hudson River, from Guttenburg to Tubbyhook	...do	1-10, 000	1855	......do	485
Hudson River, Guttenburg to Jersey City	...do	1-10, 000	1857	H. L. Whiting	610
Hudson River, from Bulls' Ferry to Fort Washington	...do	1-10, 000	1857	......do	609
Hudson River, from Spuyten Duyvel Creek to Yonkers	...do	1-10, 000	1859	H. L. Whiting and C. Rockwell.	810
Hudson River, from Spuyten Duyvel Creek to Fort Washington.	...do	1-10, 000	1853	F. H. Gerdes	418
Hudson River, from Spuyten Duyvel Creek to Sounding Point.	...do	1-10, 000	1853	......do	419
Hudson River, King's Bridge and vicinity	...do	1-10, 000	1839	T. A. M. Craven	113
From North Castle to Hudson River at Tarrytown	...do	1-10, 000	1839	......do	111
From Field West to Round Hill	...do	1-10, 000	1839	......do	110
Hudson River, Greensburgh and vicinity	...do	1-10, 000	1839	......do	112
Hudson River, from Yonkers to Hastings	...do	1-10, 000	1859	C. Rockwell	811
Hudson River, from Hastings to Tarrytown	...do	1-10, 000	1853	F. H. Gerdes	420
Hudson River, vicinity of Godwinsville	...do	1-10, 000	1840	H. L. Dickens	132
Hudson River, Hastings to Irvington	...do	1-10, 000	1860	J. Mechan	800
Hudson River, from Irvington to Paulus Hook Mountain	...do	1-10, 000	1859	......do	770
Hudson River, from Sing Sing to Stony Point	...do	1-10, 000	1854	F. H. Gerdes	468
Hudson River, Tarrytown to Croton	...do	1-10, 000	1853	......do	421
Hudson River, from near Tarrytown to Croton	...do	1-10, 000	1862-'64	H. L. Whiting	968
Hudson River, west side, from Hook Mountain to Haverstraw.	...do	1-10, 000	1864	......do	969
Hudson River, from Croton Point to Baker's Hill and Bald Hill.	...do	1-20, 000	1839	H. L. Dickens	95
Hudson River, from Haverstraw Bay to Anthony's Nose	...do	1-10, 000	1854	F. H. Gerdes	480
Hudson River, from Anthony's Nose to Cold Spring	...do	1-10, 000	1861	John Mechan	1010
Hudson River, from Cold Spring to Newburgh	...do	1-10, 000	1861	......do	1011
Rondout Creek	...do	1-5, 000	1858	C. Fendall	727
Esopus Creek	...do	1-5, 000	1858	......do	726
Hudson River, from New Baltimore to Ten Eyck	...do	1-5, 000	1856	A. Strauss	692
Hudson River, above New Baltimore	...do	1-10, 000	1856	A. S. Wadsworth	596
Hudson River, from Albany, No. 1	...do	1-10, 000	1856	......do	593
Hudson River, from Albany, No. 2	...do	1-10, 000	1856	......do	594
Hudson River, from Albany, No. 3	...do	1-10, 000	1856	......do	595
From Fort Lee to Jersey City	New Jersey	1-10, 000	1837	Charles Renard	17
From Jersey City to Caven Point	...do	1-10, 000	1855	A. S. Wadsworth	482
From Fort Lee to Boomper's Neck	...do	1-10, 000	1839	T. A. Jenkins	96
From North Scalenburg to Passaic River	...do	1-10, 000	1839	......do	97
Passaic River and Newark Neck	...do	1-10, 000	1858	F. W. Dorr	734
From Paterson to Weasel, (interior)	...do	1-10, 000	1839	T. A. Jenkins	99
From Weasel Mount to Springfield, (interior)	...do	1-10, 000	1839	......do	102
Springfield, (interior)	...do	1-10, 000	1839	......do	103
Bergen Neck to Centreville to New Jersey Railroad	...do	1-10, 000	1858	F. W. Dorr	733
From Hackensack to Newark and Elizabethtown	...do	1-10, 000	1839	T. A. Jenkins	100
From Hackensack to Paterson, (interior)	...do	1-10, 000	1839	......do	98
Western part of Newark Bay and Staten Island Sound	...do	1-10, 000	1858	F. W. Dorr	739

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
From Jersey Point to Constable Point	New Jersey	1-10,000	1837	Charles Renard	18
From Caven Point to Constable Point	do	1-10,000	1855	A. S. Wadsworth	489
Kill Von Kull and Newark Bay	do	1-10,000	1855	do	533
New Market, (interior)	do	1-10,000	1840	T. A. M. Craven	134
Bound Brook, (interior)	do	1-10,000	1840	do	135
New Brunswick and vicinity	do	1-10,000	1840	do	136
Sand Hills and vicinity	do	1-20,000	1840–'41	do	137
Princeton and vicinity, (interior)	do	1-20,000	1840	F. H. Gerdes	127
Interior, between Princeton, Trenton, and Pennington	do	1-20,000	1841	T. A. M. Craven	144
Between Shrewsbury and Princeton, (interior)	do	1-20,000	1841	H. L. Dickens	145
From Shrewsbury to New Brunswick, (interior)	do	1-20,000	1840	B. F. Sands	122
From Elizabethtown, eastward	do	1-10,000	1836	Charles Renard and T. H. Jenkins.	10
From Perth Amboy to Elizabethtown	do	1-10,000	1836	Charles Renard	8
From Perth Amboy to Woodbridge	do	1-10,000	1835	Hull Adams	534
Raritan Valley, from Perth Amboy to New Brunswick	do	1-10,000	1836	Charles Renard	11
Elizabethport to Rahway Creek	do	1-10,000	1855	A. S. Wadsworth	530
Belleville, (interior)	do	1-10,000	1839	T. A. Jenkins	101
Rahway, (interior)	do	1-10,000	1839	do	104
South Rahway, (interior)	do	1-10,000	1840	T. A. M. Craven	133
Fresh Kills, southward	do	1-10,000	1855	A. S. Wadsworth	531
Raritan Bay, from East Point to South Amboy	do	1-10,000	1855	A. M. Harrison	542
Raritan Bay, from Cowhead to Point Comfort	do	1-10,000	1855	do	541
Raritan and South Rivers	do	1-5,000	1873	F. H. Gerdes	1354 *a b*
Navesink to South Amboy	do	1-20,000	1836	Charles Renard	7
From Navesink to Poplar Creek	do	1-10,000	1839	B. F. Sands	114
Sandy Hook and Highlands of Navesink	do	1-10,000	1855	A. M. Harrison	486
Sandy Hook shore-line	do	1-10,000	1853	F. H. Gerdes	413
Sandy Hook, northward of Ocean House	do	1-10,000	1851	R. M. Bache	242
Sandy Hook	do	1-20,000	1850	H. L. Whiting	278
Sandy Hook	do	1-5,000	1836	Charles Renard	239
Sandy Hook, resurvey of	do	1-5,000	1862	H. L. Whiting	894
Sandy Hook Island	do	1-20,000	1848	S. A. Gilbert	252
North and South Shrewsbury Rivers	do	1-10,000	1865	C. M. Bache	1005
Shrewsbury River, south	do	1-10,000	1866	do	1022
From Poplar Creek to Manasquam	do	1-10,000	1839	B. F. Sands	115
Coast between Deal and Squam Beach	do	1-10,000	1867	C. M. Bache	1083
Interior, in vicinity of Squam	do	1-20,000	1842	H. L. Dickens	158
Coast between Squam Village and Barnegat Bay	do	1-10,000	1868	C. M. Bache	1084
New Jersey Coast, Barnegat to Toms River	do	1-20,000	1874	do	1371
Manasquam to Metiticonck	do	1-10,000	1839	B. F. Sands	116
Metiticonck to Cedar Creek	do	1-10,000	1839	do	117
From Metiticonk to Barnegat Inlet	do	1-20,000	1839	Charles Renard	120
New Jersey coast, from Manahawken to Barnegat	do	1-20,000	1873	C. M. Bache	1315 *b*
New Jersey coast, from Tuckerton to Manahawken	do	1-20,000	1872	do	1315 *a*
Mullican River, from Port Republic to Green Bank	do	1-10,000	1873	H. M. De Wees	1318
Little Egg Harbor and part of Mullican River	do	1-20,000	1871	C. M. Bache	1333
Interior, Goose Creek and Good Luck Point	do	1-20,000	1842	H. L. Dickens	159
Vicinity of Goose Creek, (interior)	do	1-20,000	1842	do	160
From Cedar Creek to Barnegat	do	1-10,000	1839	B. F. Sands	118
Barnegat Inlet	do	1-10,000	1866	C. Fendall	1015
From Barnegat Inlet to Great Swamp	do	1-20,060	1839	Charles Renard, B. F. Sands	121
From Barnegat Bay to Little Egg Harbor	do	1-20,000	1839–'41	B. F. Sands	119
From Little Egg Harbor to Dry Inlet	do	1-20,000	1841	do	142
From Dry Inlet to Great Egg Harbor	do	1-10,000	1841	do	143
Absecom Inlet	do	1-10,000	1864	H. W. Bache	952
Absecom Inlet and vicinity	do	1-20,000	1869–'70	C. M. Bache	1166
From Great Egg Harbor to Corson's Inlet	do	1-10,000	1842	B. F. Sands	146
From Corson's Inlet to Cape May Court-House	do	1-10,000	1842	do	147
From Cape May Court-House to Cape May Island	do	1-10,000	1842	G. D. Wise	148
From Cape May Light to Cape May Court-House	do	1-10,000	1842	George D. Wise	149
From Cape May Court-House to Dennis' Creek	do	1-10,000	1842	F. H. Gerdes	153
From Goshen to Fishing Creek, peninsula of Cape May	do	1-10,000	1843	do	154

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
From Ben Davis' Point to Dennis Creek, Delaware Bay.	New Jersey	1-20,000	1842	F. H. Gerdes	152
From Greenwich Creek to Dennisville, (interior)	...do	1-20,000	1842	H. L. Whiting	157
From Greenwich Creek and Cobansey to Salem Creek.	...do	1-20,000	1842	......do	155
From Liston Point to Ben Davis' Point	New Jersey and Delaware.	1-10,000	1841	F. H. Gerdes	141
From Liston Point to Ben Davis' Point, Delaware River	New Jersey	1-20,000	1841	......do	63
From Salem Creek to opposite Penn Grove	...do	1-20,000	1843	H. L. Whiting	156
From Salem Creek to Penn Grove	...do	1-10,000	1846	J. J. S Hassler	163
Schuylkill River, from League Island to Grey's Ferry, and from Grey's Ferry to Suspension Bridge.	Pennsylvania	1-5,000	1873	H. G. Ogden	1313 *a b*
League Island channel and vicinity	...do	1-2,500	1865	R. M. Bache	975
Stakes in the Gut east of the bridge, League Island	...do	1-2,500	1865	......do	975 *bis*
From Lazaretto to mouth of Schuylkill River	New Jersey and Pennsylvania.	1-10,000	1842	W. M. Boyce	164
Lazaretto to Dupont's Wharf	...do	1-20,000	1846	J. J. S. Hassler	162
From Penn's Grove to Lazaretto	...do	1-10,000	1841-'2	W. M. Boyce	161
Part of Philadelphia and New Jersey side of Delaware River.	...do	1-5,000	1843	......do	166
Part of Philadelphia, Camden, N. J., and vicinity	...do	1-10,000	1843-'71	W. M. Boyce, A. Lindenkohl.	165
From Cowperthwaite to Cooper's Point, Rancocus Creek.	...do	1-10,000	1843-'44	J. J. S. Hassler	168
From Rancocus Creek to Burlington and Bristol	...do	1-10,000	1843-'4	......do	167
From Bristol to New Cold Island	...do	1-10,000	1843-'4	......do	171
From New Cold Island to White Hill	...do	1-10,000	1843'-4	......do	173
From White Hill to Trenton	...do	1-10,000	1843-'4	George D. Wise	172
From Wilmington to Pea Patch Island	New Jersey and Delaware.	1-10,000	1841	F. H. Gerdes	138
From Pea Patch Island to Liston's Tree	...do	1-10,000	1841	......do	140
Wilmington to Newcastle	Delaware	1-10,000	1839	......do	139
Wilmington to Iron Hill, (interior)	Delaware and Maryland.	1-20,000	1843	T. W. Werner	169
From Ash Signal to Rigg's Hill, (interior)	...do	1-20,000	1843	......do	170
Bombay Hook Island to Mispillion Light	Delaware	1-20,000	1842	F. H. Gerdes	150
From Mispillion Light to Cape Henlopen	...do	1-20,000	1842	......do	151
From Cape Henlopen to Indian River	...do	1-20,000	1845	J. J. S. Hassler	226
Salt Point Beach to Dromedary Signal	Delaware and Maryland.	1-20,000	1850	George D. Wise	299
Beach House to South Birch	Maryland	1-20,000	1849	......do	263
Head of Assateague Bay to Pope's Island	...do	1-20,000	1850	......do	264
From Pope's Island Beach to Lonesome Hill	...do	1-20,000	1850	......do	311
Assateague Island and Parker's Bay	...do	1-20,000	1859	C. Ferguson	763
Lonesome Hill to Chincoteague Inlet	...do	1-20,000	1849	George D. Wise	522
Coast southward to Little Inlet	...do	1-20,000	1849	......do	524
Chincoteague Inlet and Bay	Virginia	1-20,000	1858	N. S. Finney	704
Chincoteague Bay	...do	1-20,000	1858	C. Ferguson	723
Chincoteague Inlet and vicinity	...do	1-20,000	1856	George D. Wise	580
Wallop's Island and Assawaman Island	...do	1-20,000	1851	W. M. Johnson	378
From Wallop's Island to westward of Gargathy Inlet.	...do	1-20,000	1855	George D. Wise	492
From Gargathy to Wachapreague Inlet	...do	1-20,000	1852-'4	......do	464
Wachapreague Inlet and vicinity	...do	1-20,000	1852	......do	510
Little Machipongo, Paramore's Island, and Wachapreague.	...do	1-20,000	1852	......do	512
Great and Little Machipongo Inlets	...do	1-20,000	1852	......do	511
Great Machipongo Inlet to Little Inlet	...do	1-20,000	1853	......do	523
New Inlet southward to Smith's Island Light	...do	1-20,000	1852	......do	525
From New Inlet to Cape Charles	...do	1-20,000	....	......do	509
Entrance to Chesapeake Bay, (practice sheet)	...do	1-20,000	1853	S. A. Wainwright	394
From Cherrystone Inlet southward to Corten's Station	...do	1-20,000	1852	John Seib	495
Occohannock, Naswaddox, and Hunger's Creeks	...do	1-20,000	1851	......do	350
From Sandy Point to Pungoteague Creek	...do	1-20,000	1850	J. Seib, S. A. Wainwright.	307
Pungoteague Creek to Chesconnessex and Onancock Creek.	...do	1-20,000	1850	......do	308
Pocomoke Sound and Bay	...do	1-20,000	1851	......do	349

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Tangier Island and Watts Island	Virginia	1-20,000	1850	J. Seib, S. A. Wainwright	309
Pocomoke Sound, from Guilford Creek to Messanger	....do	1-20,000		S. A. Wainwright	529
Pocomoke Sound, Ape's Hole Creek	Maryland	1-20,000		......do	528
From Fox Island to Little Annemessex River	....do	1-20,000	1849-'51	R. D. Cutts, J. Seib, and S. A. Wainwright.	272
Deil's Island and Manokin River	....do	1-20,000	1849	......do	270
Smith's Island, Chesapeake Bay	....do	1-20,000	1849	John Seib	271
Bloodsworth Island and South Marsh Island	....do	1-20,000	1849	......do	269
Tangier Sound and Wicomico River	....do	1-20,000	1849	R. D. Cutts, J. Seib, and S. A. Wainwright.	268
Fishing Bay and part of Nanticoke River	....do	1-20,000	1849	..... do	267
Part of Nanticoke River, vicinity of Vienna	....do	1-20,000	1849	J. Seib, S. A. Wainwright	266
Mouth of Honga River and Hooper's Straits	....do	1-20,000	1848	R. D. Cutts, J. Seib	265
Honga River, upper part	....do	1-20,000	1848	R. D. Cutts	255
Meekin's Neck, (included in No. 255)	....do	1-20,000	1854	H. L. Whiting	451
Sharp's Island, Chesapeake Bay	....do	1-20,000	1848	George D. Wise	251
Mouth of Choptank River, Cook's Point to Cambridge	....do	1-20,000	1847	R. D. Cutts	225
Little Choptank River, from Meekin's Neck to Cook's Point.	....do	1-20,000	1847-'8	George D. Wise	250
Choptank River, from Handbrook's Point to Cabin Creek.	....do	1-20,000	1848	R. D. Cutts	253
Choptank River, from Cabin Creek to Wing's Landing	....do	1-20,000	1848	......do	254
Saint Michael's River and Thirdhaven Creek	....do	1-20,000	1847	......do	224
From Ward's Point to Locust Point, Sharp's Island, and Poplar Island.	....do	1-20,000	1846-'7	George D. Wise	215
Kent Island, Eastern Bay, Wye and Saint Michael's Rivers.	....do	1-20,000	1847	R. D. Cutts	223
Kent Island base and vicinity	....do	1-10,000	1844	H. L. Whiting	181
Part of Kent Island	....do	1-20,000	1847	R. D. Cutts	222
Mouth of Chester River	....do	1-20,000	1846	J. C. Neilson	200
Shores of Chester River	....do	1-20,000	1846	.....do	201
From Swan Creek to Eastern Neck Inlet	....do	1-20,000	1846	R. D. Cutts	199
From Swan Point to Wharton Point and Pool's Island	....do	1-20,000	1845	.....do	187
Sassafras River entrance	....do	1-20,000	1854	H. L. Whiting	469
Sassafras River	....do	1-20,000	1846	J. J. S. Hassler	279
Elk River	....do	1-20,000	1860	H. Adams	788
Elk and Bohemia Rivers and Back Creek	....do	1-20,000	1845-'55	J. J. S. Hassler and H. L. Whiting.	186
North-East River entrance	....do	1-10,000	1844-'5	J. J. S. Hassler	185
North-East River	....do	1-10,000	1844-'5	.....do	184
Susquehanna River, Havre de Grace and Port Deposit	....do	1-10,000	1845	R. D. Cutts	189
Head of Chesapeake Bay, from Havre de Grace to Speoutie Creek.	....do	1-10,000	1845	.....do	188
Head of Chesapeake Bay, from Susquehanna River to Bush River.	....do	1-20,000	1845	George D. Wise	212
From Swan Creek to Bush River	....do	1-20,000	1845-'6	R. D. Cutts	190
Bush, Gunpowder, Bach, and Middle Rivers	....do	1-20,000	1846-'7	George D. Wise	213
From Bush River to Baltimore City	....do	1-20,000	1846	R. D. Cutts	197
Back River	....do	1-20,000	1846-'7	George D. Wise	214
North chop of Back River, Miller's and Pool's Islands	....do	1-20,000	1854	H. L. Whiting	450
Patapsco Neck, Bear Creek to North Point	....do	1-20,000	1853	...do	436
Patapsco River, eastern shore	....do	1-20,000	1845-'6	George D. Wise	218
Patapsco River, eastern shore	....do	1-20,000	1845-'6	...do	219
Patapsco River	....do	1-20,000	1847	...do	221
Patapsco River, western shore	....do	1-20,000	1846	...do	220
Patapsco River, from Colgate Creek to Bear Creek	....do	1-20,000	1852	H. L. Whiting	401
Patapsco River, north shore, from Fort Marshall to Bear Creek.	....do	1-10,000	1866	C. T. Iardella	1004
Patapsco River, south shore	....do	1-10,000	1865	...do	983
Patapsco River	....do	1-10,000	1851-'53	J. B. Glück, H. L. Whiting	306
Baltimore City	....do	1-10,000	1845	George D. Wise	216
Baltimore City	....do	1-10,000	1849	J. B. Glück	217
Vicinity of Baltimore, west side	....do	1-10,000	1863	J. W. Donn	920

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Vicinity of Baltimore, northwest side	Maryland	1-10,000	1864	C. M. Bache	936
Baltimore and vicinity, northeast side	...do	1-10,000	1864	C. T. Iardella	955
Vicinity of Baltimore, west side	...do	1-10,000	1865	...do	977
From Sandy Point and Merrick to Bodkin Point	...do	1-10,000	1844	F. H. Gerdes	175
From Sandy Point to Thomas Point and mouth of Severn River.	...do	1-10,000	1844	...do	174
Magothy River, Chesapeake Bay	...do	1-10,000	1845	...do	179
Severn River, Hackett's Point, to Cedar Point	...do	1-10,000	1844	...do	176
Severn River (included in No. 176)	...do	1-10,000	1844	...do	177
South River, Chesapeake Bay	...do	1-20,000	1847	George D. Wise	248
South River (included in No. 248)	...do	1-20,000	1847	...do	249
South River (included in No. 176)	...do	1-10,000	1844	...do	178
From Sanders' Point to Chew's and West River	...do	1-20,000	1846	R. D. Cutts	198
From Chew's to Parker's Creek	...do	1-20,000	1847	J. J. S. Hassler	280
From Parker's Creek to Cove Point	...do	1-20,000	1847	...do	281
Cove Point and vicinity	...do	1-20,000	1852	John Seib	388
Patuxent River entrance, Cove Point to Drum Point	...do	1-20,000	1848	R. D. Cutts	256
Patuxent River, from Point Peterson to Rattle Creek	...do	1-10,000	1860	H. Adams	812
Patuxent River, from Rattle Creek to God's Grace Point	...do	1-10,000	1860	...do	813
Patuxent River, from God's Grace Point to Point Sollin	...do	1-10,000	1859	...do	814
Patuxent River, from Point Sollin to Point Jones	...do	1-10,000	1859	...do	815
Jenkins' Creek, Cambridge, Oyster Point, and Jamaica Point.	...do	1-20,000	1848	R. D. Cutts, John Seib	257
Potomac River entrance	...do	1-20,000	1849-'56	...do	458
Saint Mary's River	...do	1-20,000	1858-'9	H. Adams	776
Saint George's Island, Saint Mary's River	...do	1-20,000	1859	...do	804
Potomac River, from Saint George's River to Higgins's Point.	...do	1-20,000	1868	J. W. Donn	1103
Potomac River, from Clement's Bay to Swan Point	...do	1-20,000	1868	...do	1105
Potomac River, from Smith's Point to Fair Oaks	Maryland and Virginia.	1-20,000	1862	C. Hosmer	865
Potomac River, from Smith's Point to Nanjemoy Store.	Maryland	1-20,000	1862	A. W. Longfellow	863
Yeocomico and Coan Rivers	Virginia	1-20,000	1868	J. W. Donn	1102
Nomini and Currioman Bays	...do	1-20,000	1868	...do	1104
Mattox Creek and part of Nomini Creek	...do	1-20,000	1868	...do	1106
Potomac River, from Cobb Point to Swan Point	Maryland	1-20,000	1862	C. Hosmer	858
Potomac River, from Swan Point to the Trunk	...do	1-20,000	1862	J. Mechan	859
Potomac River, from Cedar Point to Nanjemoy Store	...do	1-20,000	1862	...do	862
Potomac River, from Lone Point to Persimmon Point	Virginia	1-20,000	1862	...do	860
Potomac River, from Metomkin Point to Persimmon Point.	Maryland and Virginia.	1-20,000	1862	H. L. Whiting	861
Potomac River, from Metomkin Point to Aquia Creek.	Virginia	1-20,000	1862	J. Mechan	864
Potomac River, from Shipping Point to High Point	...do	1-20,000	1862	...do	867
Potomac River, from Fair Oaks to Indian Head	Maryland	1-20,000	1862	A. W. Longfellow	866
Potomac River, from Indian Head to Fox Ferry	Maryland and Virginia.	1-20,000	1862	C. Hosmer	875
Potomac River, from Broad Creek to Oxen Hill	Maryland	1-10,000	1863	A. M. Harrison	902
Potomac River, vicinity of Rosier's Bluff	Virginia	1-5,000	1862	...do	895
Jones's Point, Potomac River	...do	1-10,000	1863	...do	905
Jones's Point, near Alexandria, continuation of special survey.	...do	1-1,000.	1863	C. M. Bache	909
Potomac River, from Jones's Point to Little Falls Bridge	...do	1-15,000	1863	C. H. Boyd	910
Alexandria to Mount Vernon	...do	1-15,000	1864	J. Mechan	947
Alexandria to Bailey's Cross-Roads	...do	1-15,000	1864	F. W. Dorr	941
Alexandria to Burke's Station	...do	1-15,000	1864	...do	949
Arlington, part of, Sheet No. 1	...do	1-1,200	1864	E. Hergesheimer	1025
Arlington, part of, Sheet No. 2	...do	1-1,200	1864	...do	1026
Topography around Fort Lyon	...do	1-10,000	1863	C. M. Bache	916
Bailey's Cross-Roads to Miner's Hill	...do	1-15,000	1864	C. Rockwell	942
Dogue Run to Fairfax road	...do	1-15,000	1861	J. Mechan	948
Manassas, rebel defences	...do	1-10,000	1862	H. L. Whiting and C. M. Bache.	848
Forts Ethan Allen and Marcy, vicinity of	...do	1-15,000	1864	T. W. Robbins	951

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Forts Chaplin, Mahan, and Sedgwick	Dist. of Columbia	1-10,000	1865	C. M. Bache	1036
Aqueduct to Chain Bridge (Little Falls)	...do	1-15,000	1864	Dorr, Meehan, and Robbins.	943
Chain Bridge to Prospect Hill	...do	1-15,000	1864	F. W. Dorr	944
Potomac River, from Georgetown to foot of Little Falls	...do	1-2,500	1872	C. Junkin	1340
Potomac River, from Rushville to Great Falls	Maryland	1-10,000	1865	John W. Donn	990
Potomac River, from Young's Island to Rushville	...do	1-10,000	1865	......do	989
Potomac River, from White's Ferry to Young's Island	...do	1-10,000	1865	......do	988
Potomac River, from Hester's Island to White's Ferry	...do	1-10,000	1865	......do	987
Potomac River, from Berlin to Hester's Island	...do	1-10,000	1865	......do	986
Potomac River, from Sharpsburg to Berlin	...do	1-10,000	1865	......do	985
Williamsport and vicinity	...do	1-20,000	1862	J. Meehan and C. Hosmer	879
Upper Potomac, from High Knob to Shepherdstown	Maryland and Virginia.	1-10,000	1865-'66	J. W. Donn	1014
Upper Potomac, from Lock No. 36 to High Knob	...do	1-10,000	1866	......do	1013
Vicinity of District of Columbia (southeast portion)	Maryland	1-15,000	1863	......do	925
From Bladensburg to Leesboro, adjacent to District of Columbia.	...do	1-15,000	1863	C. Ferguson	903
Northeast side of District of Columbia	...do	1-15,000	1863-'64	Ferguson and Adams	950
Tenallytown to Great Falls	...do	1-15,000	1864	F. W. Dorr	945
Tenallytown to Rockville	...do	1-15,000	1864	Rockwell and Donn	946
Entrances to Great Wicomico and Potomac Rivers	Virginia	1-20,000	1850-'56	John Seib	500
Ingram's Bay, Dividing Creek, and Fleet's Bay	...do	1-20,000	1850	John Seib and S. A. Wainwright.	310
Rappahannock River entrance	...do	1-20,000	1851-'56	John Seib	521
Rappahannock River	...do	1-10,000	1856	Hull Adams	603
Rappahannock River, Machim's Creek to Stiff	...do	1-10,000	1857	......do	660
Rappahannock River, Bailey's Bluff to Machim's Creek	...do	1-10,000	1857	......do	659
Rappahannock River and Currotoman	...do	1-10,000	1857	......do	661
Rappahannock River, Lagrange to Punch Bowl	...do	1-10,000	1856	......do	602
Rappahannock River, Punch Bowl to Layton	...do	1-10,000	1855	John Seib and A. Strausz	520
Rappahannock River, Layton to Accaceek Point	...do	1-10,000	1855	......do	519
Rappahannock River, from Accaceek Point to Ferry Marsh.	...do	1-10,000	1855	......do	518
Rappahannock River, from Ferry Marsh to Cliff	...do	1-10,000	1855	......do	517
Rappahannock River, from Cliff to Leeds	...do	1-10,000	1855	......do	516
Rappahannock River, from Leeds to Brick Quarter	...do	1-10,000	1855	......do	515
Rappahannock River, from Brick Quarter to Holland Point.	...do	1-10,000	1854	John Seib	514
Rappahannock River, from Holland Point to Lamb Creek.	...do	1-10,000	1853-'54	......do	513
Rappahannock River, from Taylor to Falmouth	...do	1-10,000	1853	......do	434
Rappahannock River, from above Corbin's Neck	...do	1-10,000	1853	......do	435
Rappahannock River, part of the left bank in the vicinity of Fredericksburg.	...do	1-10,000	1862	T. W. Robbins	872
Fredericksburg, vicinity of	...do	1-10,000	1862	C. M. Bache	871
Rappahannock River, reconnaissance of roads, part of left bank.	...do	1-10,000	1862	T. W. Robbins	873
Accomack County, part of	...do	1-20,000	1862	C. Hosmer	868
Line across the Peninsula of Eastern Virginia, Accomack County.	...do	1-20,000	1862	A. M. Harrison	890
East Shore of Virginia, Broadwater, Sheet No. 1	...do	1-20,000	1869-'70	J. W. Donn	1203
East Shore of Virginia, Broadwater, Sheet No. 2	...do	1-20,000	1869-'70	......do	1202 *a*
East Shore of Virginia, Broadwater, New Inlet and North Branches.	...do	1-20,000	1871	......do	1202 *b*
East Shore of Virginia, Broadwater, Sheet No. 4	...do	1-20,000	1871	......do	1200
East Shore of Virginia, Broadwater, Sheet No. 3	...do	1-20,000	1869-'70	......do	1201
East Shore of Virginia, head of Machipongo River	...do	1-20,000	1871	......do	1204
Piankatank River	...do	1-20,000	1869	......do	1100
Chesapeake Bay, from Wolf Trap to Cherry Point	...do	1-20,000	1853	John Seib	503
Mobjack Bay, tributary of Chesapeake	...do	1-20,000	1853	......do	504
Mobjack Bay, North, Ware, and Severn Rivers	...do	1-20,000	1860-'68	G. D. Wise and J. W. Donn	1101
Mouth of York River	...do	1-20,000	1853-'54	John Seib	496

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
York River, from Wormley to Clay Bank	Virginia	1-20,000	1857	John Seib	685
York River, from Clay Bank to Mount Folly	do	1-20,000	1857-'58	do	686
York River, from Mount Folly to West Point	do	1-20,000	1858	do	722
Back River and Pocosin River entrances	do	1-20,000	1853-'54		499
Old Point Comfort, and entrances to Hampton Roads	do	1-20,000	1853-'54	John Seib	502
Hampton Roads and vicinity	do	1-20,000	1853	do	501
Craney Island	do	1-1,200	1874	J. W. Donn	1376
Elizabeth River entrance	do	1-20,000		John Seib	498
Plans of confederate fortifications, Elizabeth River	do	1-2,500	1862	A. M. Harrison	851
United States navy-yard, Gosport and Rebel battery at Saint Helena, opposite the navy-yard.	do	1-2,500	1862	do	850
Norfolk Harbor	do	1-10,000	1856	John Seib	506
Norfolk, Portsmouth, and Gosport	do	1-10,000	1874	C. M. Bache	1332
James River entrance	do	1-20,000	1853	John Seib	497
Nansemond River, upper part	do			do	505
Nansemond River, sheets 4 and 5	do	1-10,000	1874	C. M. Bache	1352 *a b*
Nansemond River, sheet 1	do	1-10,000	1874	do	1353
Newport News Point	do	1-10,000	1865	E. Hergesheimer	1008
James River, Newport News to Pagan Creek	do	1-20,000	1871-'72	J. W. Donn	1265
James River, Pagan Creek to Point of Shoal light-house.	do	1-20,000	1872-'73	do	1266
James River, Burwell's Bay, (Point of Shoal light-house,) to College Creek.	do	1-20,000	1873	do	1289
James River, College Creek to Chicahominy River	do	1-20,000	1873-'74	do	1290
Chicahominy River (2 sheets)	do	1-20,000	1873-'74	do	1337 *a b*
James River, Maycox Point to City Point	do	1-10,000	1853	John Seib	431
James River, City Point to Curls' Neck	do	1-10,000	1853	do	430
James River, from Curls' Neck to Dutch Gap	do	1-10,000	1853	do	429
James River, Trent's Reach	do	1-5,000	1853	S. A. Wainwright	393
James River, from Dutch Gap to Wilton	do	1-10,000	1853	John Seib	428
James River, from Warwick Bar to Richmond Bar	do	1-5,000	1853	S. A. Wainwright	392
James River, from Drewry Island to Mayo's Bridge	do	1-5,000	1853	do	391
Richmond City	do	1-5,000	1857-'58	H. Adams	684
Appomattox River, from City Point to Walthall	do	1-10,000	1853	John Seib	390
Part of Appomattox River and Petersburg	do	1-10,000	1853	John Seib, S. A. Wainwright.	389
Lynn Haven Roads	do	1-20,000	1852	John Seib	507
Cape Henry	do	1-20,000	1859	J. J. S. Hassler, J. Mechan.	758
Back Bay	do	1-20,000	1859	do	743
North River	do	1-20,000	1859	J. Mechan	754
Head of Currituck Sound	Virginia & North Carolina.	1-20,000	1858	J. J. S. Hassler, J. Mechan	736
Currituck Sound	North Carolina	1-20,000	1857	J. J. S. Hassler	657
Currituck Sound, from North Banks to Jones's Hill	do	1-20,000	1851-'52	do	381
Currituck Sound, from North Banks to North River	do	1-20,000	1848-'49	do	292
Pasquotank River, from entrance to Floating Bridge	do	1-20,000	1847	J. C. Neilson	207
Camden and Wade's Points, Albemarle Sound	do	1-20,000	1861	J. Mechan	837
Big Flatty River, Albemarle Sound	do	1-20,000	1847	J. C. Neilson	208
Little River and environs, Albemarle Sound	do	1-20,000	1847	do	209
Perquimons River, Albemarle Sound	do	1-20,000	1847	do	210
Albemarle Sound, from Smith's Point to Sandy Point	do	1-20,000	1848	J. J. S. Hassler	247
Albemarle Sound, from Laurel Point to Smith's Point	do	1-20,000	1848	do	211
Chowan River, mouth of, Albemarle Sound	do	1-20,000	1860-'61	J. Mechan	824
Chowan River, from mouth to Coleraine	do	1-20,000	1874	H. Adams	1335 *a*
Chowan River, Coleraine to Harrold's Landing	do	1-20,000	1874	do	1335 *b*
Roanoke River, mouth of, Albemarle Sound	do	1-20,000	1861	do	836
Roanoke, Eastmost, Middle, and Cashai Rivers and vicinity.	do	1-20,000	1864	R. E. Halter	923
Albemarle Sound, from Long Shoal to Laurel Point	do	1-20,000	1848	J. J. S. Hassler	246
Alligator River, from Cypress Creek to Long Shoal	do	1-20,000	1849	A. W. Longfellow	284
Alligator River, from Cypress Point to Bear Point	do	1-20,000	1849	do	285
Albemarle Sound, Durant's Island, Hollivar	do	1-20,000	1848-'49	J. J. S. Hassler	293
Durant's Island, Albemarle Sound	do	1-20,000	1861	J. Mechan	825

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Roanoke Sound, Kill Devil Hills to Nag's Head	North Carolina		1851	J. J. S. Hassler	351
Roanoke Island, part of	...do	1-20,000	1861	J. Mechan	826
Croatan Sound and lower end of Roanoke Island	...do	1-20,000	1864	R. E. Halter	933
Bodie's Island, Nag's Head to Wreck	...do	1-20,000	1849	A. W. Longfellow	354
Bodie's Island, part of	...do	1-20,000	1860	J. Mechan	791
From Wreck Stafford to Bay Signal	...do	1-20,000	1852	Hull Adams	367
From Bay Signal to Cape Hatteras	...do	1-20,000	1852	.....do	377
From Cape Hatteras to Hatteras Inlet	...do	1-20,000	1860	J. Mechan	790
Cape Hatteras to Hatteras Inlet	...do	1-20,000	1872	C. T. Iardella	1246
From Hatteras Inlet to Great Swash	...do	1-20,000	1860	John Mechan	792
Hatteras Inlet	...do	1-20,000	1852	Hull Adams	372
Hatteras Inlet	...do	1-10,000	1857	J. Mechan	623
Ocracoke Inlet	...do	1-10,000	1857	.....do	622
Ocracoke Inlet	...do	1-20,000	1852	Hull Adams	376
Pungo River	...do	1-20,000	1872	F. W. Dorr	1273
Pungo River, upper part of, Pungo Point to Leachville	...do	1-20,000	1873	.....do	1310
Pamplico Sound, Willow Point to Swanquarter	...do	1-20,000	1873-'4	C. T. Iardella	1355
Pamplico River, from Rumley Marshes to Ragged Point	...do	1-20,000	1871	F. W. Dorr	1210
Pamplico River, from Maul's Point to Rodman's Point	...do	1-20,000	1871	.....do	1211
Pamplico River, from Adams's Point to Rumley Marshes	...do	1-20,000	1871	.....do	1212
Pamplico River, from light-house to Indian Island	...do	1-20,000	1871	.....do	1213
Washington and its environs	...do	1-10,000	1872	.....do	1274
Bay River, Pamplico Sound	...do	1-20,000	1869	.....do	1094
Shore-line, from Bay River to Pamplico Sound	...do	1-20,000	1869	.....do	1095
Cedar Island and vicinity	...do	1-20,000	1872	C. T. Iardella	1277*ab*
Portsmouth Island and part of Core Beach	...do	1-20,000	1866	C. Fendall	1016
Main shore of Core Sound, from Hall's Point to Willie's Mill.	...do	1-20,000	1873	C. T. Iardella	1306
Core Sound, northeast part of	...do	1-20,000	1866	W. H. Dennis	1020
Core Sound, southwest part of	...do	1-20,000	1866	.....do	1017
Neuse River, from Newbern to Johnson's Point. (See 928.)	...do	1-10,000	1866	F. W. Dorr	1031
Neuse River, from Johnson's Point to Beard's Creek	...do	1-20,000	1866	.....do	1018
Neuse River, from Beard's Creek to Wilkinson Point	...do	1-20,000	1867	.....do	1051
Neuse River, from Wilkinson Point to Cedar Point	...do	1-20,000	1867	.....do	1052
Neuse River, from Cedar Point to Brown's Creek	...do	1-20,000	1868	.....do	1073
Neuse River, from Brown's Point to Point of Marsh	...do	1-20,000	1868	.....do	1074
Neuse River, shore-line. (See 1031)	...do	1-20,000	1863-'4	A. Strausz	928
Goldsboro, western approaches, including its defenses	...do	1-10,000	1865	F. W. Dorr	970
Goldsboro, eastern approaches to	...do	1-10,000	1865	C. Rockwell	971
Cape Lookout and part of Core Sound	...do	1-20,000	1853	A. S. Wadsworth	416
Beaufort Harbor	...do	1-10,000	1851	H. L. Whiting	315
Beaufort Harbor	...do	1-10,000	1851	Charles P. Bolles	348
Beaufort Harbor	...do	1-20,000	1854	A. S. Wadsworth	438
Beaufort Harbor, resurvey	...do	1-10,000	1862	A. Boschke	874
North and Newport Rivers	...do	1-20,000	1873	C. M. Bache	1328
Bogue Sound, from Broad Creek to Queen's Creek	...do	1-20,000	1871	H. Adams	1215
Bogue Sound, part of	...do	1-10,000	1867	A. W. Longfellow	1110
Bear Inlet to New River Inlet, coast of North Carolina	...do	1-20,000	1872	C. M. Bache	1291
New Inlet, including Federal Point, Zeek's and Smith's Islands.	...do	1-10,000	1865	J. S. Bradford	999
New River and part of Stump Sound	...do	1-10,000	1856	A. S. Wadsworth, J. Mechan.	558
Topsail Sound and Stump Sound	...do	1-10,000	1856	.....do	565
Topsail Sound, from Water's Bay to Old Topsail Inlet	...do	1-20,000	1857-'8	J. Mechan	711
Rich Inlet and Topsail Sound	...do	1-10,000	1857	.....do	617
Middle Sound and Topsail Sound	...do	1-10,000	1857	.....do	618
Masonboro Inlet and Middle Sound	...do	1-10,000	1857	.....do	619
Myrtle Sound	...do	1-10,000	1857	.....do	620
Myrtle Sound and Federal Point	...do	1-10,000	1857	.....do	621
Cape Fear entrance and Smith's Islands	...do	1-10,000	1851-'56	Charles P. Bolles	346
Oak Island, Cape Fear entrance, and Smithville	...do	1-10,000	1851	.....do	343
Cape Fear River, lower part and approaches	...do	1-10,000	1858	.....do	708

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Cape Fear River, lower part, including New Inlet	North Carolina	1-10,000	1858	Charles P. Bolles	709
Cape Fear River, Bay Lights to Reeve's Point	...do	1-10,000	1851-'2-'56	.....do	341
Cape Fear River, Reeve's Point to Hill Lane	...do	1-10,000	1853	C. P. Bolles, J. W. Gregorie	446
Cape Fear River and Campbell's Island	...do	1-10,000	1853	Charles P. Bolles	449
Cape Fear River and mouth of Brunswick Creek	...do	1-5,000	1853	.....do	447
Cape Fear River and mouth of Northwest River	...do	1-10,000	1853	.....do	448
Cape Fear River entrance and westward	...do	1-10,000	1852	.....do	674
Lockwood Folly Inlet and vicinity	...do	1-10,000	1856	.....do	673
From Lockwood Folly to Bacon's Inlet	...do	1-10,000	1857	.....do	672
Coast of South Carolina, North Island eastward	South Carolina	1-20,000	1872	O. H. Tittmann	1280 a b
North Island toward Little River; Little River and vicinity.	...do	1-20,000	1873	.....do	1295 a b
Part of Santee River and vicinity	...do	1-20,000	1873	W. H. Dennis	1308
Winyah Bay and vicinity	...do	1-20,000	1872	.....do	1276
Winyah Bay and Georgetown Harbor	...do	1-10,000	1857	S. A. Wainwright, H. L. Whiting.	527
Winyah Bay and Georgetown Harbor	...do	1-10,000	1857	.....do	526
Georgetown Harbor	...do	1-20,000	1857-'8	H. L. Whiting	834
Near Cape Romain	...do	1-20,000	1874	W. H. Dennis	1347
Bull's Bay	...do	1-20,000	1857	W. S. Edwards	772
Dewes and Caper's Islands	...do	1-20,000	1855-'7	Lt. Comman'r J. N. Maffit	681
Part of Long Island, Breach Inlet to Rattlesnake Inlet.	...do	1-20,000	1854	R. M. Bache	471
Charleston Harbor, north side, and Sullivan's Island	...do	1-10,000	1849-'58	S. A. Gilbert, W. S. Edwards.	262
Charleston Harbor, south side, to Light-House Inlet	...do	1-10,000	1849	W. S. Edwards, S. A. Gilbert.	261
Charleston City and vicinity	...do	1-10,000	1857-'8	W. S. Edwards	710
Morris Island and vicinity	...do	1-10,000	1858	John Seib	715
Part of Folly Island	...do	1-20,000	1849-'50	S. A. Gilbert	293
Folly Island and vicinity	...do	1-20,000	1858	John Seib	714
Folly Island, west end to Kiawah Island	...do	1-20,000	1854	R. M. Bache	491
Morris Island and Folly Island	...do	1-10,000	1864	W. H. Dennis	964
Defenses of Charleston	...do	....	1865	C. O. Boutelle	976
Stono River, mouth of, and rebel earthworks of Cole's Island.	...do	1-20,000	1862	C. Rockwell	899
Rebel earthworks on Cole's Island and fort at Old Battery, Stono River.	...do	1-10,000 1-2,500	1862	.....do	900
North Edisto River, northeastern part	...do	1-20,000	1851	George D. Wise	322
North Edisto River, southwestern part	...do	1-20,000	1851	.....do	327
Part of Edisto Island, and Jehossee Island	...do	1-20,000	1856-'7	John Seib	679
South Edisto River	...do	1-20,000	1852	.....do	508
Saint Helena Sound	...do	1-20,000	1856-'67	John Seib, W. H. Dennis	611
Saint Helena and Lady's Islands	...do	1-20,000	1872	Charles Hosmer	1275
Coosaw River and vicinity	...do	1-20,000	1865-'67	W. H. Dennis	996
Pocotaligo Bridge, vicinity of	...do	1-10,000	1865	F. W. Dorr	974
From Tripp's Inlet to Port Royal Sound	...do	1-20,000	1859-'67	J. Seib, C. Rockwell, and W. H. Dennis.	840
Daw Island to Port Royal Sound	...do	1-20,000	1859	J. Seib, C. Rockwell	839
Parry and Cane's Islands	...do	1-20,000	1868	C. Hosmer	1070
Port Royal and vicinity	...do	1-20,000	1865	W. H. Dennis	1006
Port Royal Island, Coosaw River to Ashepoo River	...do	1-10,000	1873	Charles Hosmer	1307 a b
Broad River, southern part of	...do	1-20,000	1865	R. E. Halter	998
Broad River, shores of	...do	1-20,000	1865	.....do	997
Between Broad and May Rivers, containing hydrography	...do	1-20,000	1870-'1	C. Hosmer	1195
From Port Royal Sound to mouth of May River	...do	1-20,000	1859-'60	C. Rockwell	809
From May River to Savannah River	...do	1-20,000	1859-'60	.....do	803
From Savannah River to Cooper River, west of Danfuskie Inlet, containing hydrography.	...do	1-20,000	1870-'1	C. Hosmer	1196
Savannah River, forts Jackson and Lee, batteries Tattnall and Barnwell.	...do	1-5,000	1866	C.O. Boutelle, H. L. Marindin.	1027
Coast of South Carolina	...do	1-20,000	1872	O. Tittman	1280 a
Coast of South Carolina	...do	1-20,000	1872	.....do	1280 b
Savannah River, mouth of	Georgia	1-5,000	1874	C. Hosmer	1349

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Savannah River, entrance to Four Mile Point	Georgia	1-10,000	1852	H. L. Whiting	379
Cross Tides to Head of Isla Island, Savannah River	...do	1-10,000	1852	......do	380
Savannah River, Elba Island, part of river	...do	1-5,000	1874	Charles Hosmer	1348 *a b*
Savannah River, City and Elba Island	...do	1-5,000	1852	H. L. Whiting	383
Savannah City and environs	...do	1-10,000	1852	......do	343
Savannah City and vicinity, northward	...do	1-10,000	1852	......do	385
Savannah, vicinity of	...do	¾ in. to 1 m.	1865	W. H. Dennis	972
Wassaw Sound and vicinity	...do	1-20,000	1863	......do	906
Wilmington River and estuaries	...do	1-20,000	1865	C. Fendall	992
Romerly Marsh Creek	...do	1-20,000	1869	C. Hosmer	1089
Ossabaw Sound and vicinity	...do	1-20,000	1858	A. M. Harrison	706
From Ossabaw Sound to Saint Catherine's Sound	...do	1-20,000	1858-'9-'60	H. S. Du Val	841
Ogeechee Sound and vicinity	...do	1-10,000	1858	A. M. Harrison	707
Ogeechee, Vernon, and Burnside	...do	1-20,000	1865	C. Fendall	991
Ogeechee to Medway Bay	...do	1-20,000	1869	C. Hosmer	1109
Saint Catherine's Island and vicinity	...do	1-20,000	1867	C. Rockwell, J. A. Sullivan	1060
Between Medway and Julienton Rivers	...do	1-20,000	1869	C. Hosmer	1155
Sapelo Sound and vicinity	...do	1-20,000	1857-'8	A. W. Longfellow	721
Sapelo Island (reconnaissance)	...do	1-10,000	1857	H. S. Du Val	678
Doboy Sound and vicinity	...do	1-20,000	1868	W. H. Dennis	1080
Altamaha Sound and vicinity	...do	1-20,000	1869	......do	1114
Darien City	...do	1-20,000	1869	......do	1114 *bis*
Saint Simon's Sound	...do	1-10,000	1856-'7	A. W. Longfellow	750
Saint Simon's and Long Islands	...do	1-20,000	1869	C. T. Iardella	1103
Blythe Island and Brunswick Harbor	...do	1-10,000	1856-'58	A. W. Longfellow	778
Mackay's River and vicinity	...do	1-20,000	1869	W. H. Dennis	1113
Saint Andrew's Sound and vicinity	...do	1-20,000	1869-'70	C. M. Bache	1145
Cumberland Island, part of	...do	1-20,000	1870	W. H. Dennis	1152
Cumberland Island, base site (reconnaissance)	...do	1-10,000	1857	A. M. Harrison	624
Chickamauga battle-field	...do	1-20,000	1864	C. H. Boyd	934
Summit of Lookout Mountain	Georgia and Tennessee.	1-10,000	1865	......do	973
Saint Mary's River and vicinity	Georgia and Florida	1-10,000	1857	A. M. Harrison	614
Eastern coast of Florida	Florida	1-40,000	1873	......do	1298
Fernandina Harbor and vicinity	...do	1-10,000	1857	......do	613
Amelia River and vicinity	...do	1-10,000	1857	......do	615
Nassau Sound and vicinity	...do	1-20,000	1871	W. H. Dennis	1232 *a*
Sisters Creek	...do	1-20,000	1871	......do	1232 *b*
Saint John's River entrance	...do	1-10,000	1864	......do	965
Saint John's River and Fort George Inlet	...do	1-10,000	1853	R. M. Bache	411
Saint John's River, from entrance to Brown's Creek	...do	1-10,000	1855	A. M. Harrison	550
Saint John's River, Brown's Creek to Point Suarrez	...do	1-10,000	1855	......do	551
Saint John's River, Point Suarrez to Jacksonville	...do	1-10,000	1855-'56	......do	552
Jacksonville and vicinity	...do	1-10,000	1864	W. H. Dennis	963
South of Saint John's River, from entrance to General E. Hopkins's plantation.	...do	1-10,000	1858	J. Mechan	712
South of Saint John's River, from General Hopkins's to Diego Plains.	...do	1-10,000	1858	......do	713
Diego Plains	...do	1-20,000	1861	F. W. Dorr	822
North and Guano Rivers, part of	...do	1-20,000	1860	......do	784
Saint Augustine and vicinity	...do	1-10,000	1859-'60	......	783
Coast from Saint Augustine to Matanzas Inlet	...do	1-20,000	1867	C. M. Bache	1082
Matanzas River and vicinity	...do	1-20,000	1872	A. M. Harrison	1268
Florida Peninsula, from Point Padgett to Point Andrew (triangulation sketch).	...do	1-69,000	1859	Capt. M. L. Smith	765
Mosquito Inlet and vicinity	...do	1-20,000	1874	A. M. Harrison	1344
Halifax River	...do	1-20,000	1874	......do	1343
Cape Canaveral	...do	1-20,000	1850	Hull Adams	300
Indian River	...do	1-10,000	1861	C. Ferguson	785
Coast of Florida, Miami River, and Key Biscayne Bay	...do	1-20,000	1851	Hull Adams	330
Head of Key Biscayne Bay	...do	1-20,000	1867	C. T. Iardella	1049
Key Biscayne, from Shoal Point to Black Point	...do	1-20,000	1859	......do	744
Key Biscayne, from Turtle Point to Fender Point	...do	1-20,000	1859	......do	745

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topography.	Registered number.
Card's Sound, from West Arsenicker to Jew Point	Florida	1-20, 000	1859	C. T. Iardella	746
Barnes's Sound	...do	1-20, 000	1859	......do	747
Barnes's Sound, part of	...do	1-20, 000	1859	......do	758
Barnes's Sound, part of	...do	1-20, 000	1860	......do	857
Barnes's Sound	...do	1-40, 000	1870	J. G. Oltmanns	1151
Shore and keys of Barnes's Sound	...do	1-30, 000	1868	C. T. Iardella	1071
Elliott's Key, Soldier Key, and Ragged Key	...do	1-20, 000	1852-'3	Hull Adams	409
Elliott's Key, Cæsar's Creek, and Old Rhodes' Key	...do	1-20, 000	1853	.....do	408
Key Largo, Old Rhodes' to Basin Hill	...do	1-20, 000	1854-'5	S. A. Wainwright	573
Key Largo, Basin Hill to Excelsior	...do	1-20, 000	1855	.....do	574
From Egan Creek to Indian Key	...do	1-20, 000	1857	.....do	640
Long Island, Mud and Captain Key	...do	1-20, 000	1857	F. W. Dorr	690
Upper Matecumb and Windley's Island	...do	1-20, 000	1858	C. T. Iardella	696
Buchanan and adjacent keys	...do	1-20, 000	1859	.....do	748
Oyster and adjacent keys	...do	1-20, 000	1859	.....do	749
Lower Matecumb and Lignumvitæ Keys	...do	1-20, 000	1857	S. A. Wainwright	641
Lower Matecumb and Long Key	...do	1-20, 000	1858	C. T. Iardella	694
Duck Channel and Conch Keys and part of Long Key	...do	1-20, 000	1857	F. W. Dorr	688
Crawl, Grassy, and Tom Harbor Keys, and part of Flat Deer Key.	...do	1-20, 000	1857	.....do	689
Vaccas Keys	...do	1-20, 000	1857	.....do	651
Bahia Honda, or Spanish Harbor	...do	1-20, 000	1854	S. A. Wainwright	461
Bahia Honda Harbor, Pine Island Signal	...do	1-20, 000	1851	Hull Adams	339
Little Pine Key, Johnson's Flat Key, and other adjacent keys.	...do	1-20, 000	1857	C. T. Iardella	627
Howe's Key, Annetta, Spanish, and others	...do	1-20, 000	1857	.....do	626
Big Pine Key, Ramrod Key, and others adjacent	...do	1-20, 000	1857	.....do	625
Sugar-Loaf, Cudjoe, Summerland, and Loggerhead Keys	...do	1-20, 000	1856	.....do	563
Content, Water, Raccoon, and Knock-'em-down Keys	...do	1-20, 000	1857	F. W. Dorr	652
Johnston's and Sawyer's Keys	...do	1-20, 000	1856	S. A. Wainwright	560
Snipe and Saddle-Bunch Keys	...do	1-20, 000	1855	Hull Adams	494
Mudd Keys	...do	1-20, 000	1855	.....do	493
Boca Chica and adjacent keys	...do	1-20, 000	1853	R. M. Bache	417
Keys north and east of Boca Chica	...do	1-20, 000	1853-'4	Hull Adams	457
Key West, Stock Island, and adjacent keys	...do	1-10, 000	1850	......do	291
Key off the harbor of Key West	...do	1-20, 000	1850	......do	302
Keys and ledges, vicinity of Key West	...do	1-10, 000	1850	......do	301
Marquesas Key and Boca Chica	...do	1-20, 000	1851	......do	319
Charlotte Harbor, approaches to	...do	1-20, 000	1859	F. W. Dorr and C. Ferguson	738
Charlotte Harbor, approaches to	...do	1-20, 000	1859	......do	739
Charlotte Harbor, from Boca Grande entrance to South Boca Nueva Pass.	...do	1-20, 000	1860	C. T. Iardella	853
Charlotte Harbor, part of	...do	1-20, 000	1860	.....do	854
Charlotte Harbor, from El Gabo to Peas Creek	...do	1-20, 000	1860	......do	855
Peas Creek, head of Charlotte Harbor	...do	1-20, 000	1860	......do	856
Pine Island Sound, Charlotte Harbor	...do	1-20, 000	1866-'7	.....do	1048
Bayport and vicinity (western part)	...do	1-20, 000	1860	N. S. Finney	962
Boca Ceiga Bay, south part; Mullet, Egmont Passage, and north end of Palm Key.	...do	1-20, 000	1872-'3	A. Braid	1316 *a b*
Tampa Bay; Passage Key to Palmasola Point; Tampa Bay; Palmasola Point to Piney Point	...do	1-20, 000	1874	H. G. Ogden	1346 *a b*
Clearwater Harbor	...do	1-20, 000	1873	......do	1301
From Raccoon Point to Chassahowitzka River	...do	1-20, 000	1859	N. S. Finney	782
From Chassahowitzka River to Homosassa River	...do	1-20, 000	1860	......do	781
From Homosassa River to Green Point	...do	1-20, 000	1858-'9	......do	779
Homosassa River	...do	1-10, 000	1857	.....do	691
Crystal Reefs and Rivers	...do	1-20, 000	1858	......do	705
From Crystal River to Withlacoochee Bay	...do	1-20, 000	1859	......do	780
Withlacoochee River (reconnaissance)	...do	1-10, 000	1856	A. M. Harrison	570
From the Waccasassa to the Withlacoochee River	...do	1-20, 000	1858	N. S. Finney	699
Waccasassa Reefs	...do	1-10, 000	1856	A. M. Harrison	571
Waccasassa River (reconnaissance)	...do	1-10, 000	1856	......do	569
Cedar Keys and vicinity, eastward	...do	1-10, 000	1856	......do	572

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Cedar Keys	Florida	1-10,000	1852-'54	F. H. Gerdes	423
Cedar Keys	...do	1-10,000	1852	.....do	422
Ocilla River	...do	1-20,000	1854	G. D. Wise	454
From Ocilla River to Saint Mark's River	...do	1-20,000	1859-'60	.....do	819
Saint Mark's River	...do	1-20,000	1856	.....do	575
From Saint Mark's River to Ocklockony Bay	...do	1-20,000	1859-'60		820
Ocklockony Bay	...do	1-20,060	1859	G. D. Wise	771
Alligator Harbor and Saint George's Sound	...do	1-20,000	1858	C. T. Iardella	695
Saint George's Sound from Royal Bluff, including Dog Island.	...do	1-20,000	1858	G. D. Wise	697
From Green Point, Apalachicola Bay, to East Pass, Saint George's Sound.	...do	1-20,000	1856-'7	.....do	647
Apalachicola entrance	...do	1-20,000	1858	.....do	646
Delta of Apalachicola River	...do	1-20,000	1857	.....do	648
Apalachicola River	...do	1-20,000	1857	.....do	601
Saint Vincent Sound and Island	...do	1-20,000	1858	.....do	698
Saint Joseph's Bay, Cape San Blas and vicinity	...do	1-20,000	1868	H. M. De Wees	1065
Saint Joseph's Bay to Saint Andrew's Point	...do	1-20,000	1869	.....do	1091
Saint Andrew's Bay, eastern and western branches	...do	1-20,000	1870	C. T. Iardella	1146
Saint Andrew's Bay and Sound	...do	1-20,000	1855	G. D. Wise	477
Saint Andrew's Bay, northern branch	...do	1-20,000	1870	C. T. Iardella	1147 *a*
Saint Andrew's Bay, eastern branch	...do	1-20,000	1870	.....do	1147 *b*
Western arm of Saint Andrew's Bay	...do	1-20,000	1871	H. M. De Wees	1187
Saint Andrew's Bay to Choctawhatchee Bay (3 sheets)	...do	1-20,000	1872	F. W. Perkins	1358 *a b c*
Choctawhatchee Bay, western part	...do	1-20,000	1872	Herbert G. Ogden	1269
Choctawhatchee Bay, eastern part	...do	1-20,000	1872	.....do	1270
Choctawhatchee Bay and Santa Rosa Sound	...do	1-20,000	1871	.....do	1191
Santa Rosa Sound, from longitude 86° 43' to 86° 58'	...do	1-20,000	1871	.....do	1192
Santa Rosa Sound, from longitude 86° 58' to 87° 7'	...do	1-20,000	1871	.....do	1193
Western part of Santa Rosa Sound, Pensacola Bay	...do	1-10,000	1859	F. H. Gerdes	701
Pensacola Bay, entrance	...do	1-10,000	1856	.....do	566
Pensacola Bay, west side	...do	1-20,000	1858	.....do	700
Pensacola Bay, navy-yard to Emmanuel's Point	...do	1-10,000	1856	.....do	567
Part of Pensacola, Escambia, and East Bays	...do	1-20,000	1858	.....do	717
Coast between Pensacola and Mobile, west part of Big Lagoon.	...do	1-10,000	1867	J. G. Oltmanns	1034
Santa Maria de Galvaez Bay	...do	1-20,000	1860	F. H. Gerdes	797
Coast between Pensacola from Lagoon to mouth of Perdido Inlet.	Florida and Alabama.	1-10,000	1867	J. G. Oltmanns	1035
Coast between Pensacola from Perdido entrance to East Gulf shore.	...do	1-10,000	1867	.....do	1042
Entrance to Mobile Bay	Alabama	1-20,000	1868	.....do	1066
Bon Secour Bay, Little Point Clear to Cypress Point	...do	1-20,000	1849	W. E. Greenwell	276
Bon Secour Bay, from Mullet to Cypress Point	...do	1-20,000	1849	.....do	277
Mobile Bay, Mullet to Ragged Point	...do	1-20,000	1849	.....do	296
Mobile Bay, Ragged Point to Vessel Point	...do	1-10,000	1849	.....do	294
Mobile Bay, upper part	...do	1-20,000	1850	.....do	288
Mobile City	...do	1-20,000	1850	.....do	295
Mobile Bay, Choctaw Point to Deer River	...do	1-20,000	1850	.....do	287
Mobile River, Deer River Point to Cedar Point	...do	1-20,000	1849	.....do	275
Mobile Bay entrance and Dauphin Island	...do	1-20,000	1847	.....do	240
Dauphin Island, base-line and vicinity	...do	1-10,000	1846-'51	F. H. Gerdes	326
Dauphin Island Spit	...do	1-10,000	1853	W. E. Greenwell	406
Mississippi Sound, Grand Batture to Grand Point	Mississippi	1-20,000	1848	W. E. Greenwell, F. H. Gerdes.	243
Mississippi Sound, Grand Batture to West Pascagoula River.	...do	1-20,000	1848	W. E. Greenwell	273
Petit Bois Island, Mississippi Sound	...do	1-20,000	1848	.....do	245
Horn Island, entrance to Mississippi Sound	...do	1-10,000	1847	.....do	241
Horn Island, Mississippi Sound	...do	1-20,000	1849	.....do	274
From West Pascagoula River to Biloxi Bay	...do	1-20,000	1851	.....do	323
Biloxi Harbor, Town, and Back Bay	...do	1-10,000	1851	.....do	324

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Deer Island, Mississippi Sound	Mississippi	1-10, 000	1852		384
Ship Island, Mississippi Sound	do	1-20, 000	1848	W. E. Greenwell	244
Ship Island, Mississippi Sound	do	1-10, 000	1853	do	407
Cat Island and Isle au Pied	do	1-20, 000	1848	do	242
From Mississippi City to Pitcher Point	do	1-20, 000	1852	do	369
Harbor of Pass Christian	do	1-10, 000	1851	do	325
Bay of Saint Louis and town of Shieldsboro	do	1-20, 000	1852	do	370
Malheureaux Island, Pearl River to Point Clear	do	1-20, 000	1852	do	371
Pearl Island and vicinity	do	1-20, 000	1856	R. M. Bache	633
Approaches to Vicksburg	do	1-10, 000	1863	C. Fendall	935
Approaches to Grand Gulf	do	1-5, 000	1864	F. H. Gerdes	937
Mississippi Sound, Isle à Pitre to Nine Mile Bayou	Louisiana	1-20, 000	1853	W. E. Greenwell	404
Eastern and southern shores of Lake Borgne	do	1-20, 000	1853	do	405
Lake Borgne, from Fort Wood to Proctorville	do	1-20, 000	1857	W. S. Gilbert	629
Lake Borgne, from Proctorville to Point au Marchett	do	1-20, 000	1857	do	628
Lakes Borgne and Pontchartrain, passes connecting	do	1-20, 000	1858	do	773
The Rigolets	do	1-20, 000	1855	R. M. Bache	656
Lake Pontchartrain, from Salt Bayou to Bayou Bonfuca	do	1-20, 000	1859	W. S. Gilbert	774
Lake Pontchartrain, from Bayou Bonfuca to Ragged Point	do	1-20, 000	1860	M. Seaton	796
Lake Pontchartrain, from Bayou Le Bar to Bayou Coushon	do	1-20, 000	1860	M. Seaton, W. S. Gilbert	799
Point aux Herbs	do	1-20, 000	1859	W. S. Gilbert	786
Chandeleur Sound, western shore from Sandfly to Crabtree.	do	1-20, 000	1858-'59	S. Harris	768
Chandeleur Sound, western shore from Barrel Key to Point Chico.	do	1-20, 000	1858-'59	do	769
Chandeleur Sound, west side from Morgan Harbor to Indian Mound Bay.	do	1-20, 000	1871	C. H. Boyd	1198
Chandeleur Islands, from Sunrise Shell Bank to Martin's Island.	do	1-20, 000	1857	J. E. Hilgard	654
Chandeleur Islands, northern part	do	1-10, 000	1852	F. H. Gerdes	366
Chandeleur Islands	do	1-20, 000	1855	J. E. Hilgard, J. G. Oltmanns.	548
Chandeleur Islands	do	1-20, 000	1855	do	549
Isle au Breton Sound, Deep Water to California Point	do	1-20, 000	1868-'69	C. H. Boyd	1096
Isle au Breton Sound, California Point to Mozambique Point.	do	1-20, 000	1869	do	1098 *a*
Isle au Breton Sound, California Point	do	1-20, 000	1869	do	1098 *b*
Isle au Breton Sound, south side	do	1-20, 000	1869	do	1097
Isle au Breton Sound, Gardner's to Otter Bayou	do	1-20, 000	1869-'70	do	1099
Isle au Breton Sound, Otter Bayou to Point Comfort	do	1-20, 000	1870	do	1148
Isle au Breton Sound, Errol Island	do	1-20, 000	1869	do	1092
Pass à l'Outre	do	1-20, 000	1859-'60	F. H. Gerdes	794
Mississippi Delta, Southwest Pass, part of South Pass, East, West, and Garden Island Bays.	do	1-20, 000	1867	J. W. Donn	1037
Mississippi Delta, South Pass, Bayou Grand, and East Pass.	do	1-20, 000	1867	do	1038
Mississippi River	do	1-20, 000	1873	C. H. Boyd	1300
Mississippi River, from Cubit Crevasse to the forts and Bird Island Sound.	do	1-20, 000	1868	do	1069
Fort Jackson, plan of, showing the effect of bombardment on 18th to 24th April, 1862.	do	1-600	1862	F. H. Gerdes, J. S. Harris	870
Mississippi River, from the forts to Grand Prairie	do	1-20, 000	1870	C. H. Boyd	1149
Mississippi River, from Grand Prairie to Point à la Hache.	do	1-20, 000	1871	do	1197
Mississippi River, from Bohemia to Poverty Point	do	1-20, 000	1872	do	1258 *a*
Mississippi River, Poverty Point to Jesuits' Church	do	1-20, 000	1872	do	1258 *b*
Isle Dernière, western part	do	1-10, 000	1853	F. H. Gerdes	410
Atchafalaya Bay, entrance	do	1-10, 000	1855	do	636
Atchafalaya Bay, eastern side	do	1-10, 000	1855	do	637
Atchafalaya Bay, eastern side	do	1-10, 000	1855	do	638
Atchafalaya Bay, north side	do	1-10, 000	1855	do	639
Atchafalaya Bay, northwest part	do	1-20, 000	1857	do	632
Côte Blanche Bay, eastern part	do	1-20, 000	1857	do	631

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
West Côte Blanche Bay, part of	Louisiana	1-20, 000	1859	F. H. Gerdes, J. G. Oltmanns.	764
West Côte Blanche Bay, part of	...do	1-20, 000	1860	......do	793
Sabine Pass	Texas	1-20, 000	1874	J. N. McClintock	1356
Galveston, East Bay, and Bolivar Peninsula	...do	1-20, 000	1851	J. M. Wampler	329
Galveston entrance, harbor, and city	...do	1-20, 000	1850	......do	282
Galveston Bay, Lawrence Cove to Stevenson's	...do	1-20, 000	1851	......do	330
Galveston Bay, Lawrence Cove to San Jacinto Bay, inclusive.	...do	1-20, 000	1851	......do	331
Galveston Bay, Highland Bayou to Harris's Signal	...do	1-20, 000	1850	......do	283
Redfish Bar, Galveston Bay	...do	1-20, 000	1850	......do	298
Galveston, West Bay and part of Galveston Island	...do	1-20, 000	1851	......do	328
Galveston, West Bay, Galveston Island, and Chocolate Bay.	...do	1-20, 000	1852	......do	374
Coast of Gulf, from San Luis to Jupiter Station	...do	1-20, 000	1852	......do	375
From Brazos River to Matagorda Peninsula	...do	1-20, 000	1853	J. M. Wampler, J. S. Williams.	412
Matagorda Peninsula and main land opposite	...do	1-20, 000	1857	S. A. Gilbert	642
Matagorda Peninsula and Decros Point	...do	1-20, 000	1857	......do	613
Coast and part of Matagorda Bay	...do	1-20, 000	1855	J. A. Sullivan	557
Matagorda Bay	...do	1-20, 000	1857	S. A. Gilbert	600
Matagorda Bay	...do	1-20, 000	1857	......do	645
Part of Matagorda Bay, from Trespalacios River to Karankaway Bay.	...do	1-20, 000	1856	M. Seaton	737
Lavaca Bay, from Benado Creek to Cox's Bay	...do	1-20, 000	1858	......do	742
Lavaca Bay, from Garcitas Bay to Chocolate Bay	...do	1-20, 000	1858	......do	740
Indianola and environs	...do	1-20, 000	1859	W. H. Dennis, M. Seaton	752
Matagorda Island	...do	1-20, 000	1859	W. H. Dennis	1030
Matagorda and part of Espiritu Santo Bay	...do	1-20, 000	1857	S. A. Gilbert	644
Espiritu Santo Bay and part of San Antonio Bay and vicinity.	...do	1-20, 000	1859	W. H. Dennis	766
From Matagorda entrance to Aransas Pass (reconnaissance).	...do	1-50, 000	1858	S. A. Gilbert	730
San Antonio Bay, part of, and vicinity	...do	1-20, 000	1859	W. H. Dennis	767
San Antonio Bay, part of, and Saint Charles Bay	...do	1-20, 000	1860	W. S. Gilbert	828
Aransas Bay, northern part, and east end of Copano Bay.	...do	1-20, 000	1861	......do	838
Copano Bay, west end, and Saint Mary's Town	...do	1-20, 000	1861	......do	827
Aransas Bay, from Second Chain Island to Long Reef	...do	1-20, 000	1860	......do	787
Aransas Bay, part of, and entrance to Corpus Christi Bay.	...do	1-20, 000	1860-'1	......do	823
Corpus Christi Bay, Corpus Christi to McGloin's Bluff	...do	1-20, 000	1867	C. Hosmer	1043
Corpus Christi Bay, McGloin's Bluff to Mustang Island	...do	1-20, 000	1867	......do	1044
Laguna Madre, eastern shore	...do	1-20, 000	1867	C. H. Boyd	1045
Laguna Madre, western shore	...do	1-20, 000	1867	......do	1046
Rio Bravo del Norte, entrance and vicinity	...do	1-20, 000	1854	W. E. Greenwell	453
Lower part of Ohio River, between Mound City and Cairo.	Illinois	1-10, 000	1864	F. H. Gerdes, C. Fendall	938
Environs of Saint Louis (combined sheets)	Missouri	1-10, 000	1862	R. M. Bache, J. Mechan	921
Saint Louis, military defenses of	...do	1-10, 000	1862	J. Mechan	852
Vicinity and fortifications of Saint Louis	...do	1-10, 000	1862	R. M. Bache	908
Carondelet	...do	1-10, 000	1863	......do	907
Strawberry Plains and vicinity	Tennessee	1-10, 000	1864	C. Rockwell	940
Approaches and defenses of Knoxville south of Holston River.	...do	1-10, 000	1863-'4	R. A. Talcott	920
Approaches and defenses of Knoxville north of Holston River.	...do	1-10, 000	1863-'4	C. Rockwell	939
Chattanooga and its approaches	...do	1-10, 000	1863	F. W. Dorr	926
Lookout Valley and part of Lookout and Raccoon Mountains.	...do	1-10, 000	1864	J. W. Donn	966
Summit of Lookout Mountain	Tennessee and Georgia.	1-10, 000	1865	C. H. Boyd	973
Nashville, approaches to, from south and west	Tennessee	1-10, 000	1864	F. W. Dorr	931

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Nashville, environs and approaches from the north, including the town of Edgefield.	Tennessee	1-10, 000	1864	J. W. Donn	932
Los Coronados Island	California	....	1851	R. D. Cutts	332
From southern boundary to San Diego Bay	...do	1-10, 000	1852	A. M. Harrison	365
San Diego Bay, from La Carbonina to Sweet Water Valley	...do	1-10, 000	1852	.....do	364
San Diego Bay, from Point Loma to Newtown	...do	1-10, 000	1851	.....do	333
False Bay, dependency of San Diego Bay	...do	1-10, 000	1852	.....do	363
Catalina Island	...do	1-10, 000	1873	.....do	1239 *a b*
Santa Barbara Island	...do	1-10, 000	1871	A. W. Chase	1180
Point Fermin to Point Pedro	...do	1-10, 000	1854	W. M. Johnson	476
Coast from Point Fermin eastward to San Gabriel River	...do	1-10, 000	1859	.....do	892
Point Fermin to Point Saint Vincent	...do	1-10, 000	1870	A. W. Chase	1153
Point Saint Vincent northward	...do	1-10, 000	1871	.....do	1231
Coast east of San Pedro, including Wilmington	...do	1-10, 000	1872	.....do	1283
New River to Bolsas Creek	...do	1-10, 000	1873	.....do	1315
Bolsas Creek to Santa Ana River	...do	1-10, 000	1874	.....do	1369
From Point Duma to Cañada de Isique	...do	1-10, 000	1857	W. M. Johnson	703
From Cañada de Isique to Punta Mugu	...do	1-10, 000	1857	.....do	702
Cañada de Tajiguas to "Ram" Station	...do	1-10, 000	1873	W. E. Greenwell	1338
"Ram" Station to Cojo Viego	...do	1-10, 000	1873	.....do	1339
Cañada de los Pueblos to Cañada de Tajiguas	...do	1-10, 000	1871	.....do	1247
Coast from Hueneme eastward to Punta Mugu	...do	1-10, 000	1857	W. M. Johnson	893
From Hueneme Point to Santa Clara River	...do	1-10, 000	1855	.....do	576
From Santa Clara River to San Buenaventura	...do	1-10, 000	1855	.....do	683
Town of San Buenaventura and vicinity	...do	1-10, 000	1870	W. E. Greenwell	1190
Punta Gorda, toward San Buenaventura	...do	1-10, 000	1870	.....do	1189
Punta Gorda and vicinity	...do	1-10, 000	1871	A. F Rodgers	1237
Punta Gorda and Shelter Cove	...do	1-10, 000	1871	.....do	1238
Punta Gorda	...do	1-10, 000	1871	.....do	1239
Punta Gorda	...do	1-10, 000	1871	.....do	1240
Vicinity of Santa Barbara	...do	1-10, 000	1854	W. M. Johnson	470
Santa Barbara and vicinity	...do	1-10, 000	1852	A. M. Harrison	373
Santa Barbara town and vicinity	...do	1-10, 000	1870	W. E. Greenwell	1229
Santa Barbara to Sand Point	...do	1-10, 000	1869	.....do	1128
Sand Point to Gorda Point	...do	1-10, 000	1869	.....do	1127
Santa Barbara Channel, from Santa Barbara to Pelican Point.	...do	1-10, 000	1870	.....do	1230
Santa Barbara Channel, from Pelican Point to Los de Pueblos.	...do	1-10, 000	1871	.....do	1267
Anacapa and part of Santa Cruz Island	...do	1-10, 000	1855	W. M. Johnson	555
Santa Cruz and Santa Barbara Channel	...do	1-10, 000	1860	.....do	1003
Part of the island of Santa Cruz, Santa Barbara Channel	...do	1-10, 000	1859	.....do	876
Santa Rosa Island, Santa Barbara Channel	...do	1-20, 000	1872-'3	S Forney	1325
Santa Rosa Island, east end, Santa Barbara Channel	...do	1-20, 000	1872-'3	.....do	1326
San Miguel Island, Santa Barbara Channel	...do	1-20, 000	1871	.....do	1242
Point Conception (reconnaissance)	...do	....	1850	A. M. Harrison	313
Point Conception and vicinity (two sheets)	...do	1-10, 000	1869	C. Rockwell	1122 *a b*
Point Sal, southern shore	...do	1-5, 000	1867	W. E Greenwell	1055
San Luis Obispo Bay	...do	1-10, 000	1871-'2	L. A. Sengteller	1321
San Simeon Bay and vicinity	...do	1-10, 000	1871	C. Rockwell	1278
Point Pinos, Monterey Bay	...do	1-10, 000	1851	A. M. Harrison	320
Monterey Harbor	...do	1-10, 000	1851-'2	R. D. Cutts	357
Monterey Harbor	...do	1-10, 000	1854	W. M. Johnson	554
Monterey Bay northward to Salinas River	...do	1-10, 000	1854	.....do	478
Monterey Bay northward to Pajaro River	...do	1-10, 000	1854	.....do	473
Pajaro River and vicinity, Monterey Bay	...do	1-10, 000	1853	A. M. Harrison	442
Sanquel Cove and vicinity, Monterey Bay	...do	1-10, 000	1853	.....do	443
Santa Cruz Harbor, Monterey Bay	...do	1-10, 000	1853	.....do	444
Coast northward to Point Año Nuevo	...do	1-10, 000	1853	.....do	445
Point Año Nuevo and Punta del Bolsa	...do	1-10, 000	1854	W. M. Johnson	653
From Punta del Bolsa to Tunitas Creek	...do	1-10, 000	1854	.....do	682
Coast from Tunitas Creek northward	...do	1-10, 000	1866	A. F. Rodgers	1009
Half-Moon Bay	...do	1-10, 000	1861	W. M. Johnson	993

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Point San Pedro to Pillar Point	California	1-10,000	1866	A. F. Rodgers	1019
Coast from Point Pedro northward to Point Lobos	...do	1-10,000	1853	A. M. Harrison	395
Point Lobos and vicinity	...do	1-10,000	1852	.....do	382
Vicinity of Point Lobos	...do	1-10,000	1853	A. F. Rodgers	427
South Farallon Island	...do	1-5,000	1872	.....do	1259
Fort Point to Alcatraz Island	...do	1-10,000	1851	R. D. Cutts	333
Golden Gate, entrance to San Francisco Bay	...do	1-10,000	1852	.....do	359
San Francisco Bay entrance	...do	1-10,000	1850	.....do	314
San Francisco entrance	...do	1-10,000	1857	A. F. Rodgers	663
San Francisco City and vicinity	...do	1-10,000	1852	.....do	352
San Francisco City and vicinity	...do	1-10,000	1852	.....do	398
San Francisco City and vicinity	...do	1-10,000	1857-'8	.....do	687
Land approaches to San Francisco	...do	1-10,000	1867	A. W. Chase	1059
Approaches to San Francisco	...do	1-10,000	1867	C. Rockwell	1067
Approaches to S n Francisco	...do	1-10,000	1868	.....do	1068
Yerba Buena Island, San Francisco Bay	...do	1-10,000	1851	A. F. Rodgers	353
San Francisco Bay, from Cañada de Visitacion to Point San Mateo.	...do	....	1854	.....do	460
Point San Mateo to Guano Island, San Francisco Bay	...do	1-10,000	1853	.....do	413
Angelo Creek to Redwood City, San Francisco Bay	...do	1-10,000	1857	.....do	665
San Francisco Bay, Angelo Creek to Ravenswood	...do	1-10,000	1857	.....do	664
Puglas base and vicinity, San Francisco Bay	...do	1-10,000	1853	R. D. Cutts	432
San Francisco Bay, Ravenswood to Aloise	...do	1-10,000	1857	A. F. Rodgers	676
San Francisco Bay, Contra Costa	...do	1-10,000	1852	R. D. Cutts	370
Contra Costa, San Francisco Bay	...do	1-10,000	1852	.....do	378
Contra Costa, San Francisco Bay	...do	1-10,000	1853	A. M. Harrison	399
San Francisco Bay, Contra Costa to San Antonio Creek	...do	1-10,000	1856	A. F. Rodgers	591
San Francisco Bay, San Antonio Creek and Oakland	...do	1-10,000	1856	.....do	592
San Francisco Bay, Contra Costa to Beard's Creek	...do	1-10,000	1857	.....do	635
San Francisco Bay, Beard's Creek to Mowry's Creek	...do	1-10,000	1857	.....do	634
San Francisco Bay, from San Antonio Creek southward	...do	1-10,000	1855	.....do	481
San Francisco Bay, north shore, vicinity of Bluff Point	...do	1-10,000	1853	.....do	4'5
Richardson's Bay, dependency of San Francisco Bay	...do	1-10,000	1851	.....do	334
San Francisco Bay, north side entrance	...do	1-10,000	1850	.....do	321
Angel Island and Raccoon Straits, San Francisco Bay	...do	1-10,000	1852	.....do	361
Coast northward from San Francisco entrance	...do	1-10,000	1853	.....do	400
Tamalpais Peninsula and interior	...do	1-10,000	1872	.....do	1284
Tamalpais Mountain	...do	1-10,000	1873	.....do	1302
Ballenas Bay and vicinity	...do	1-10,000	1854	.....do	452
Coast adjacent to Ballenas Bluff	...do	1-10,000	1854	.....do	456
Drake's Bay, from Briones to Wild Cat	...do	1-10,000	1859-'60	.....do	807
Drake's Bay, from Wild Cat to Point No. 1	...do	1-10,000	1859-'60	.....do	806
Drake's Bay, from Point No. 1 to Punta de Los Reyes	...do	1-10,000	1859-'60	.....do	805
San Pablo Bay, from Panole Point to Molate Reef	...do	1-10,000	1856	.....do	561
San Pablo Bay, from Point Wilson to Lone Tree Point	...do	1-10,000	1856	.....do	562
Mare Island and Karquines Straits, San Pablo Bay	...do	1-10,000	1850	R. D. Cutts	316
Vicinity of Mare Island, San Pablo Bay	...do	1-10,000	1856	A. F. Rodgers	563
Karquines Strait, Suisun Bay, and city of Benicia	...do	1-10,000	1856	.....do	577
Suisun Bay	...do	1-20,000	1866	.....do	1029
Napa Creek and City	...do	1-10,000	1858	D. Keer	777
San Pablo Bay, from Long Pond to Petaluma Creek	...do	1-10,000	1856	A. F. Rodgers	564
Petaluma Creek, from entrance to Lakeville	...do	1-10,000	1860	.....do	817
Petaluma Creek, from Lakeville to Petaluma City	...do	1-10,000	1860	.....do	818
Petaluma Creek to San Pedro Point	...do	1-10,000	1854	.....do	472
Punta de Los Reyes, part of	...do	1-10,000	1862	A. F. Rodgers, D. Kerr	831
Coast north of Punta de Los Reyes, part of	...do	1-10,000	1862	.....do	882
Tomales Bay entrance	...do	1-10,000	1853-'4	J. S. Lawson	439
Tomales Bay, part of	...do	1-10,000	1862	A. F. Rodgers, D. Kerr	849
Tomales Bay, part of	...do	1-10,000	1862	.....do	880
Tomales Bay Station (reconnaissance)	...do	1-10,000	1856	C. B. Ellis	578
Coast from Tomales Bay to Salmon Creek	...do	1-10,000	1862	A. F. Rodgers, D. Kerr	883
Point Reyes	...do	1-10,000	1852-'3	J. S. Lawson	403
Point Arena and vicinity	...do	1-10,000	1870	L. A. Sengteller	1228

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Alder Creek to Welch Station, north of Point Arena	California	1-10,000	1870	L. A. Sengteller	1279
Welch Station to Cuffey Cove, north of Point Arena	do	1-10,000	1871	do	1305
Cuffey's Point to Stillwell Station, northward	do	1-10,000	1872	do	1362
Stillwell Station to Point Carbillo, Point Carbillo to Pudding Creek.	do	1-10,000	1872-'3	do	1363 a b
Shelter Cove and vicinity	do	1-10,000	1871	A. F. Rodgers	1236
Shelter Cove to Bear Harbor	do	1-10,000	1872	do	1285
Bear Harbor to Timber Ridge	do	1-10,000	1873	do	1324
Timber Ridge to Soldier Frank's Point	do	1-10,000	1873	do	1323
Soldier Frank's Point to Abalone Point	do	1-10,000	1873	do	1322
Cape Mendocino, south of	do	1-10,000	1871	do	1241
False Cape to Cape Mendocino	do	1-10,000	1869	do	1134
Centreville to False Cape	do	1-10,000	1869	do	1135
Eel River and vicinity	do	1-10,000	1869	do	1136 a
Eel River changes from 1869 to 1870	do	1-10,000	1869-'70	do	1136 b
Humboldt Bay entrance	do	1-10,000	1854	J. S. Lawson	474
Humboldt Bay to Table Bluff	do	1-10,000	1869	A. F. Rodgers	1137
Humboldt Bay	do	1-10,000	1870	do	1174
Humboldt Bay	do	1-10,000	1870	do	1175
Humboldt Bay	do	1-10,000	1870	do	1176
Coast north of Humboldt Bay	do	1-10,000	1870	do	1177
Coast south of Trinidad Head	do	1-10,000	1870	do	1178
Coast north of Trinidad	do	1-10,000	1870	do	1179
Klamath, vicinity of	do	1-10,000	1874	A. W. Chase	1370
False Klamath to Rocky Point	do	1-20,000	1873	do	1378
From Crescent City southward	do	1-10,000	1871	do	1248 b
From Sister Rock to False Klamath	do	1-10,000	1871	do	1248 a
Crescent City Harbor	do	1-10,000	1859	J. S. Lawson	741
Point Saint George and Crescent City Reef	do	1-10,000	1869	A. W. Chase	1132
From Point Saint George northward, (Lake Earl)	do	1-10,000	1870	do	1199
From Cone Station to near Oregon boundary	do	1-10,000	1870	do	1216
From Oregon boundary to Chetko River	Oregon	1-10,000	1870		1227
Smith's Hill to Mack's Reef	do	1-10,000	1872	A. W. Chase	1317
Coast of Oregon near Port Orford, (reconnaissance)	do	1-20,000	1869	do	1133
Port Orford or Ewing Harbor	do	1-10,000	1851	A. M. Harrison	347
Orford Reef	do	1-10,000	1869	A. W. Chase	1131
Cape Blanco	do	1-10,000	1869	do	1130
Entrance to Koos Bay	do	1-10,000	1861	J. S. Lawson	846
Koos Bay, sketches of	do	1-20,000	1863	do	927
Goat Island to Whale's Island	do	1-10,000	1871	A. W. Chase	1260
Cape Foulweather and entrance to Yaquina Bay	do	1-10,000	1868	do	1086
Point Adams and Sand Island, Columbia River	do	1-10,000	1851	A. M. Harrison	335
Columbia River entrance	do	1-22,762	1850-'51	W. B. McMurtrie	317
Columbia River, from Point Adams to Young's Bay	do	1-10,000	1868	C. Rockwell	1112
Columbia River, from Young's Bay to John Day's River	do	1-10,000	1868	do	1123
Columbia River, from John Day's River to Warren's Landing.	do	1-10,000	1870	do	1234
Columbia River, from Warren's Landing to Three-Tree Point.	do	1-10,000	1870	do	1235
Columbia River, from Three-Tree Point to Puget Island	do	1-10,000	1871	do	1250
Columbia River, from Cape Disappointment to Chinook Point.	do	1-10,000	1869	do	1138
Columbia River, from Chinook Point to Gray's Point	do	1-10,000	1869	do	1139 a
Columbia River, from Sandy Island to Chinook Spit	do	1-10,000	1869	do	1139 b
Columbia River, from Gray's Bay to Snag Island	do	1-10,000	1870	do	1249
Columbia River, vicinity of Kathlamet and Westport	Washington Ter.	1-10,000	1872	do	1331
Cape Disappointment	do	1-10,000	1851	A. M. Harrison	337
Shoalwater Bay, Sheet No. 1	do	1-10,000	1871	J. J. Gilbert	1261
Shoalwater Bay, Sheet No. 2	do	1-10,000	1871	do	1262
Shoalwater Bay, Sheet No. 3	do	1-10,000	1871	do	1263
Shoalwater Bay, Sheet No. 4	do	1-10,000	1871	do	1264
Shoalwater Bay, Sheet No. 5	do	1-10,000	1872	do	1292
Shoalwater Bay, Sheet No. 6	do	1-10,000	1872	do	1293

APPENDIX No. 7—Continued.

Localities.	State.	Scale.	Date.	Topographer.	Registered number.
Shoalwater Bay, sheet No. 7	Washington Ter.	1-10, 000	1872	J. J. Gilbert	1294
Shoalwater Bay (mouth of Willopah River), sheet No. 8	.. do	1-10, 000	1873	......do	1342 a b
Shoalwater Bay, sheet Nos. 9 and 10	...do	1-10, 000	1873	......do	1341 a b
Cape Flattery eastward to Nee-ah Bay	...do	1-10, 000	1852	J. S. Lawson	387
Strait of Juan de Fuca, from Cape Flattery to Nee-ah Bay.	...do	1-10, 000	1852	......do	386
New Dungeness, part of	...do	1-10, 000	1870	......do	1168
New Dungeness, Strait of Juan de Fuca	...do	1-10, 000	1855	.....do	539
Washington Harbor, Strait of Juan de Fuca	...do	1-10, 000	1870	.....do	1165
Protection Island to New Dungeness	...do	1-10, 000	1870	.....do	1169
Port Discovery entrance, sheet No. 1	...do	....	1868-'69	......do	1124
Port Discovery, sheet No. 2	.. do	....	1869	......do	1125
Port Discovery, sheet No. 3	...do	....	1869-'70	......do	1126
Port Townshend, vicinity of base	...do	1-10, 000	1856	......do	589
Port Townshend	...do	1-10, 000	1856	......do	582
Port Townshend, Admiralty Inlet	...do	1-10, 000	1856	......do	581
Killesut Harbor	...do	1-10, 000	1871	......do	1255
Oak Bay	...do	1-10, 000	1872	......do	1304
Mats Mats or Boat Harbor	...do	1-10, 000	1855	......do	540
Port Ludlow, entrance to Hood's Canal	...do	1-10, 000	1855	......do	537
Entrance to Port Gamble	...do	1-10, 000	1857	......do	671
Port Gamble, entrance to Hood's Canal	...do	1-10, 000	1856	......do	585
Hood's Canal, entrance to	...do	1-10, 000	1857	......do	669
Admiralty Inlet (two sheets)	...do	1-10, 000	1872	......do	1303 a b
Part of Admiralty Inlet	...do	1-10, 000	1857	......do	668
Apple Cove, Admiralty Inlet	...do	1-20, 000	1856	George Davidson, J. S. Lawson.	583
Murden's Cove, Admiralty Inlet	...do	1-20, 000	1856	J. S. Lawson	584
Fauntelroy, Admiralty Inlet	...do	1-10, 000	1857	George Davidson	670
Shilshole Bay, Admiralty Inlet	...do	1-10, 000	1867	J. S. Lawson	1064
Admiralty Bay, Puget Sound	...do	1-10, 000	1870	.....do	1164
Duwamish Bay	...do	1-10, 000	1856	George Davidson	590
Port Madison	...do	1-10, 000	1868	J. S. Lawson	1087
Budd's Inlet, (2 sheets)	...do	1-10, 000	1873	......do	1327 a b
Point Partridge to Eastward, Whidbey Island	...do	1-10, 000	1871	......do	1254
Finger Station to Point Partridge, Whidbey Island	...do	1-10, 000	1871	......do	1253
Deception Pass to Finger Station	...do	1-10, 000	1871	......do	1252
Smith's Island	.. do	1-10, 000	1870	......do	1170
Smith's Island, Rosario Strait	...do	1-10, 000	1855	......do	538
Strawberry Bay, Cypress Island, Rosario Strait	...do	1-10, 000	1854	.....do	462
Gulf of Georgia, southern part, from Matia Island to East Point.	....do	1-20, 000	1858	......do	730
Gulf of Georgia, southern part, from East Point to Deep Bay.	....do	1-20, 000	1858	......do	731
Gulf of Georgia, southern part, from Deep Bay to Rocky Island.	....do	1-20, 000	1858	......do	732

APPENDIX No. 8.

List of hydrographic sheets, geographically arranged, registered in the archives of the United States Coast Survey from January, 1835, to July, 1875. (Nos. 1 to 1244, inclusive.)

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Eclipse Harbor, Coast of Labrador		1-40,000	1860	A. Murray, U. S. N	818
Deep-sea soundings, Coast of Labrador, from Isle of Ponds to Cape Chudleigh.			1860	do	817
Deep-sea sounding off Cape Sable			1872-'3	J. A. Howell, U. S. N	1208
Eastport Harbor and approaches, No. 1, south part	Maine	1-10,000	1861	C. O. Boutelle	847
Eastport Harbor and approaches, No. 2, north part	do	1-10,000	1861	do	848
Quoddy Roads and Johnson's Bay	do	1-10,000	1866	H. L. Marindin	895
Off shore, from Machias Bay to Eastern Point Light	Maine, New Hampshire, Massachusetts.	1-300,000	1858-'9	A. Murray, U. S. N	700
Western entrance to Moose-a-bec Reach	Maine	1-10,000	1870-'1	F. F. Nes. H. Anderson	1060
Moose-a-bec Reach	do	1-10,000	1870-'1	do	1039
Indian River	do	1-10,000	1870-'1	do	1061
Winter Harbor and approaches	do	1-10,000	1867	H. Anderson	938
Frenchman's Bay, from Bunker's Ledge to Schooner's Head.	do	1-10,000	1873	J. W. Donn	1215
Frenchman's Bay, from Schooner's Head to Bar Harbor	do	1-10,000	1873	do	1216
Frenchman's Bay, from Bar Harbor to Sand's Point	do	1-10,000	1873	do	1217
Southwest Harbor, Mount Desert, western approach	do	1-10,000	1871	do	1120
Southwest Harbor, Mount Desert, eastern approach	do	1-10,000	1871	do	1121
Somes Sound	do	1-10,000	1871	do	1122
Placentia Bay, Mount Desert Island	do	1-10,000	1872	do	1164
Prospect Harbor	do	1-10,000	1871	H. Anderson	1127
Entrance to Isle au Haut Bay	do	1-20,000	1870	F. P. Webber	1074
Isle au Haut Bay	do	1-20,000	1869	Charles Junken	1028
Hurricane Island Sound and vicinity	do	1-10,000	1869	do	1029
The basin on Vinal Haven Island	do	1-10,000	1870	F. P. Webber	1075
Fox Island Bay and vicinity	do	1-10,000	1870	do	1073
East side of Fox Islands and Seal Bay	do	1-10,000	1871	do	1142
Fox Islands Thoroughfare, eastern part	do	1-10,000	1868	Charles Junken	983
Fox Islands Thoroughfare, western part	do	1-10,000	1868	do	982
Penobscot Bay, approaches to	do	1-20,000	1866-'7-'8	do	1051
Penobscot Bay, entrance to	do	1-20,000	1866-'7	do	943
Penobscot Bay, entrance to	do	1-10,000	1863	Edward Cordell	823 *a*
Metinic and Monhegan Islands, (2 sheets)	do	1-20,000	1867	Charles Junken	823 *b*
Penobscot Bay, from Owl's Head to Ensign Island	do	1-20,000	1869	F. P. Webber	1086
Penobscot Bay, between Owl's Head and Fox Islands	do	1-20,000	1869	Charles Junken	1030
Penobscot Bay, islands south of Islesboro	do	1-10,000	1869	F. P. Webber	1087
Penobscot Bay, from Camden to Belfast Bay	do	1-20,000	1871	do	1143
Belfast Bay	do	1-10,000	1872	H. Anderson	1168
Gilkey's Harbor, Penobscot Bay	do	1-10,000	1871	F. P. Webber	1144
Rockland Harbor	do	1-10,000	1863	W. S. Edwards	819
Camden and Rockport Harbors	do	1-10,000	1865	H. Anderson	873
Penobscot River, from Bangor to Hampden	do	1-10,000	1867	J. A. Sullivan	934
Muscle Ridge Channel	do	1-10,000	1866-'7	R. E. Halter and C. Junken	952
Muscle Ridge Islands	do	1-10,000	1867	R. E. Halter	953
Saint George's River entrance	do	1-10,000	1865	R. E. Halter and C. Fendall	872
Saint George's River (sheet No. 1)	do	1-10,000	1864-'7	F. P. Webber	858
Saint George's River (sheet No. 2)	do	1-10,000	1864	do	859
Coast from Mosquito Harbor to Seal Harbor	do	1-10,000	1866	R. E. Halter	907
Coast from Monhegan Island to Demiscove Point	do	1-20,000	1860	T. S. Phelps, U. S. N	746
Coast between Demiscove Islands and Cape Small	do	1-40,000	1859	J. Wilkinson, U. S. N	696
Muscongus Bay	do	1-10,000	1867	R. E. Halter	950

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Muscongus Bay	Maine	1-10,000	1868	R. E. Halter	986
Medunoook River and Point Pleasant Gut	...do	1-10,000	1866-'7	.....do	951
Modomak River	...do	1-10,000	1866	H. Anderson	960
Modomak River, from Bremen to Havener's Ledge	...do	1-5,000	1866	.....do	960 *bis*
John's Bay	...do	1-10,000	1867	R. E. Halter	920
Damariscotta River and approaches	...do	1-10,000	1860	J. P. Bankhead, U. S. N	791
Damariscotta River, from Newcastle to Clark's Cove	...do	1-10,000	1866	E. Hergesheimer	903
Sheepscot Bay, between Griffith's Head and Kennebec River.	...do	1-10,000	1868	J. S. Bradford	971
Sheepscot River, from Hendricks Head light to Wiscasset.	...do	1-10,000	1858	J. H. Moore, U. S. N	675
Sheepscot River, from Hendricks Head light to Wiscasset.	...do	1-10,000	1858	.....do	676
Mouth of Sheepscot River and Booth Bay	...do	1-20,000	1860	T. S. Phelps, U. S. N	771
Wiscasset Bay, Back River, and Montseag Bay to Westport bridge.	...do	1-10,000	1862	F. H. Gerdes	775
Ebenecook Harbor, Town's End Gut, Back River, &c	...do	1-10,000	1866	E. Hergesheimer	891
Hell Gate, Back River (2 sheets)	...do	1-10,000	1865	H. Anderson	893
Great and Little Hell Gates and Goose Rock Passage	...do	1-5,000	1867	J. S. Bradford	930
Hockomock and Knubble Bays, Sasanoa River	...do	1-10,000	1867	.... do	929
Hockomock Bay, including the river emptying into the Kennebec and Sheepscot Rivers.	...do	1-10,000	1862	F. H. Gerdes	776
Merrymeeting Bay and Kennebec River	...do	1-10,000	1861	.....do	790
Kennebec River entrance	...do	1-20,000	1856	S. D. Trenchard, U. S. N	552
Kennebec River, northward from Bath	...do	1-10,000	1858	J. H. Moore, U. S. N	693
Kennebec River, from Coxe's Head to Bath	...do	1-10,000	1857	S. D. Trenchard, U. S. N	639
Kennebec River, from Swan Island to Richmond	...do	1-10,000	1869	C. H. Boyd	1064
Kennebec River, from Richmond to Gardiner	...do	1-10,000	1870	.....do	1065
Vicinity of Cape Small Point	...do	1-10,000	1868	J. S. Bradford	972
New Meadow River	...do	1-10,000	1866	J. W. Donn	899
Head of Maquoit, Middle and Quohog Bays, Harpswell Sound.	...do	1-10,000	1869	H. Anderson	1008
Maquoit Bay, Mare Point Bay, and Middle Bay	...do	1-10,000	1863	F. H. Gerdes	840
Quohog Bay	...do	1-10,000	1864	A. Strauss	857
Mericoneag Sound	...do	1-10,000	1863	F. H. Gerdes	839
Off-shore soundings from Seguin Isle to Cape Elizabeth.	...do	1-40,000	1867	R. Platt, U. S. N	933
Alden's Rock	...do	1-789	1853	M. Woodhull, U. S. N	824
Casco Bay	...do	1-10,000	1856	S. D. Trenchard, U. S. N	602
Casco Bay	...do	1-10,000	1856	.....do	614
Casco Bay	...do	1-20,000	1862	E. Cordell	820
Casco Bay	...do	1-40,000	1857-'8	W. G. Temple, U. S. N	664
Casco Bay (lower part)	...do	1-20,000	1861	C. A. Schott	754
Casco Bay (part of)	...do	1-20,000	1859	J. Wilkinson, U. S. N	726
Approaches to Portland Harbor	...do	1-40,000	1864	T. S. Phelps, U. S. N	860
Portland Harbor, approaches, and positions of rocks	...do	1-20,000	1863	.....do	841
Portland Harbor, outside of entrance	...do	1-20,000	1854	M. Woodhull, U. S. N	403
Portland Harbor	...do	1-10,000	1854	.....do	404
Portland Harbor, additional soundings	...do	1-20,000	1862	Ed. Cordell	788
Rocks off Portland Harbor	...do	1-20,000	1863	T. S. Phelps, U. S. N	796
Bank off Union Wharf, Portland Harbor	...do	1-5,000	1859	J. Wilkinson, U. S. N	684
Jordon's Rock, near Portland Harbor	...do	1-5,000	1857	F. A. Roe, U. S. N	601
Bank off Union Wharf, Portland Harbor	...do	1-5,000	1857	S. D. Trenchard, U. S. N	600
Portland Harbor	...do	1-5,000	1868	R. Platt, U. S. N	949
Portland City and Harbor, sheet No. 1	...do	1-1,200	1868	H. Anderson	1032
Portland City and Harbor, sheets No. 2 and 3	...do	1-2,400	1869	.....do	1033 *a b*
Portland City and Harbor, sheets No. 4 and 5	...do	1-2,400	1869	.....do	1034 *a b*
Richmond's Island Harbor	...do	1-10,000	1850	M. Woodhull, U. S. N	243
Coast, from Cape Elizabeth to Kennebunk Port	...do	1-40,000	1859	A. Murray, U. S. N	699
From Kennebunk Port to Isles of Shoals	...do	1-40,000	1858	.....do	667
Cape Porpoise and Stage Island Harbor (*a*) Wood Island, and approaches to Saco River (*b*)	...do	1-10,000	1871	J. S. Bradford	1117 *a b*
Wood Island Harbor, reconnaissance of	...do	1-10,000	1859	A. Murray, U. S. N	739

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Stage Isl'd and Cape Porpoise Harbors, reconnaissance of	Maine	1-10, 000	1859	A. Murray, U. S. N	740
Saco River	...do	1-5, 000	1866	G. Davidson	882
Saco River, from Saco to Chandler's Point	...do	1-5, 000	1867	F. F. Nes	941
Saco River up to Chandler's Point	.. do	1-5, 000	1867	......do	942
York Harbor	.. do	1-10, 000	1853	M. Woodhull, U. S. N	376
Boon Island and York Island (outside)	...do	1-20, 000	1853	......do	366
Portsmouth Harbor and approaches	New Hampshire	1-20, 000	1851	......do	294
Portsmouth to Newburyport	New Hampshire and Massachusetts.	1-20, 000	1857	C. R. P. Rodgers, U. S. N	627
Isles of Shoals	New Hampshire	1-10, 000	1859	A. Murray, U. S. N	741 *a*
Isles of Shoals Harbor	New Hampshire and Maine.	1-10, 000	1874	R. Platt, U. S N	741 *b*
Jeff ey's Ledge	New Hampshire	1-150, 000	1863	T. S. Phelps, U. S. N	761
Coast of New Hampshire, from Pulpit Rock to Great Boar's Head.	...do	1-10, 000	1870	H. Anderson	1068
Coast of New Hampshire, from Great Boar's Head to Salisbury.	...do	1-10, 000	1870	......do	1069
Burlington Harbor, Lake Champlain	Vermont	1-10, 000	1871	F. D. Granger	1105
Mitchell's Fall's, Merrimack River	Massachusetts	200 feet to 1 inch.	1867	H. Mitchell	1012
Newburyport Harbor	...do	1-10, 000	1851	M. Woodhull, U. S. N	292
Cape Ann and Newburyport	...do	1-20, 000	1857	C. R. P. Rodgers, U. S. N	594
Ipswich and Annisquam Harbor	...do	1-10, 000	1852	M. Woodhull, U. S. N	346
Annisquam and Ipswich	...do	1-20, 000	1856	S. D. Trenchard, U. S. N	574
Annisquam to Thatcher Is'and (Cape Ann)	...do	1-10, 000	1857	C. R. P. Rodgers, U. S. N	597
Gloucester Harbor and approaches	...do	1-10, 000	1853	H. S. Stellwagen, U. S. N	396 *a*
Emerson's Point and Milk Island	...do	1-10, 000	1873	J. S. Bradford	396 *b*
Salem Harbor and approaches	...do	1-10, 000	1850-'1	C. H. McBlair, U. S. N	284
Salem Harbor	...do	1-5, 000	1858	W. G. Temple, U. S. N	651
From Lynn to Marblehead	...do	1-20, 000	1853-'4	H. S. Stellwagen, U. S. N	413
Lynn Harbor	...do	1-10, 000	1858	A. Murray, U. S. N	662
Massachusetts Bay and Stellwagen Bank	...do	1-80, 000	1854-'5	H. S. Stellwagen, U. S. N	516
Stellwagen Bank, Massachusetts Bay	...do	1-100, 000	1854	......do	457
Stellwagen's and Cohasset Rocks	...do	1-10, 000	1856	......do	582
Off-shore, between Newburyport and Monomoy	...do	1-300, 000	1857	C. R. P. Rodgers, U. S. N	593
Boston Harbor and approaches	...do	1-20, 000	1846-'7-'8	C. H. Davis, U. S. N	221
Boston Harbor (the inner harbor)	...do	1-5, 000	1846	......do	178
Boston Harbor (the inner harbor) survey under United States Harbor Commissioners.	...do	1-10, 000	1861	A. Boschke	850
Boston Harbor	...do	1-10, 000	1858	W. G. Temple, U. S. N	652
Shirley's Gut, Boston Harbor	...do	1-5, 000	1858	......do	648
Minot's Ledge, off Boston Harbor	...do	1, 500	1853	H. S. Stellwagen, U. S. N	412
Town, Fore, and Back Rivers, Weymouth	...do	1-10, 000	1869	J. S. Bradford	1021
Philip's Ledge, Green Harbor River	...do	1-40, 000	1846	C. H. Davis, U. S. N	183
Duxbury Bay	...do	1-10, 000	1867-'70	H. Anderson	1035
Plymouth Harbor	...do	1-10, 000	1853	M. Woodhull, U. S. N	422
Plymouth Harbor	...do	1-10, 000	1870	H. Anderson	1067
Barnstable Harbor	...do	1-10, 000	1861	H. Mitchell	851
Part of Barnstable Bay	...do	1-10, 000	1860	J. Wilkinson, U. S. N	772
Cape Cod, Race Point to Nausett light	...do	1-40, 000	1855-'6	H. S. Stellwagen, U. S. N	519
Provincetown Harbor, Cape Cod	...do	1-40, 000	1856	......do	578
Provincetown Harbor, Cape Cod	...do	1-10, 000	1868	A. Balbach	578 *bis*
Cape Cod, Nausett light to Monomoy	...do	1-40, 000	1856	H. S. Stellwagen, U. S. N	570
Wellfleet Harbor	...do	1-20, 000	1849-'50	C. H. McBlair, U. S. N	249
Chatham Harbor	...do	1-10, 000	1851	M. Woodhull, U. S. N	293
Monomoy Shoals	...do	1-30, 000	1853	......do	387
Monomoy Shoals	...do	1-20, 000	1872	F. D. Granger	1149
Monomoy and Nantucket Shoals	...do	1-20, 000	1873	......do	1195 *a b*
Monomoy Shoals, reconnaissance	...do	1-40, 000	1868	F. F. Nes and G. S. Blake, U. S. N.	961
Cultivator's Shoals, off Cape Cod	...do	1-20, 000	1872	J. A. Howell, U. S. N	1207 *a*
George's Shoals, off Cape Cod	...do	1-40, 000	1873	......do	1207 *b*
Phelps' Bank and Asia Rip, Nantucket Shoals, reconnaissance of.	...do	1-100, 000	1860-'1	T. S. Phelps, U. S. N	745

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Nantucket Shoals (Davis South Shoal)	Massachusetts	1-40,000	1847-'8-'9	C. H. Davis, U. S. N.	223
Off Nantucket and Martha's Vineyard (deep-sea soundings).	...do	1-400,000	1853	H. S. Stellwagen, U. S. N.	406
Nantucket Shoals (off-shore soundings)	...do	1-300,000	1853-'4-'5	...do	440
Nantucket Shoals	...do	1-40,000	1846	C. H. Davis, U. S. N.	179
Nantucket Sound (entrance)	...do	1-40,000	1856	H. S. Stellwagen, U. S. N.	569
Nantucket Sound, Nobska light to Monomoy	...do	1-40,000	1854	M. Woodhull, U. S. N.	455
Nantucket Sound, Monomoy to Bishop's and Clark's light.	...do	1-20,000	1874	F. D. Granger	1243
Nantucket Sound	...do	1-30,000	1855-'6	C. R. P. Rodgers, U. S. N.	527
Bass River	...do	1-20,000	1849	C. H. McBlair, U. S. N.	245
Hyannis Harbor	...do	1-20,000	1847	J. N. Maffit, U. S. N.	184
Nantucket Harbor	...do	1-20,000	1846	C. H. Davis, U. S. N.	181
Nantucket Harbor	...do	1-10,000	1846	...do	180
Nantucket Island (south side)	...do	1-40,000	1854	H. S. Stellwagen, U. S. N.	445
Nantucket Upper Harbor	...do	1-20,000	1872	F. D. Granger	1163
Muskeget Channel and approaches	...do	1-20,000	1851	C. H. McBlair, U. S. N.	239
Edgartown Harbor, Vineyard Sound	...do	1-20,000	1846	C. H. Davis, U. S. N.	222
Edgartown Harbor, Martha's Vineyard	...do	1-10,000	1846	...do	182
Edgartown Harbor and Catamy Bay	...do	1-10,000	1871	H. Mitchell	1126
Holmes's Hole and vicinity	...do	1-10,000	1845	G. S. Blake, U. S. N.	161
Vineyard Haven Harbor	...do	1-10,000	1871	H. Mitchell	1106
Martha's Vineyard, south side	...do	1-40,000	1853	H. S. Stellwagen, U. S. N.	378
Lone Rock, &c., between Gay Head and No Man's Land	...do	1-20,000	1852	C. H. McBlair, U. S. N.	344
Cuttyhunk to Gay Head	...do	1-40,000	1857	C. R. P. Rodgers, U. S. N.	596
Naushon and vicinity	...do	1-20,000	1857	...do	595
Buzzard's Bay, eastern side	...do	1-20,000	1845	G. S. Blake, U. S. N.	160
Buzzard's Bay, western side	...do	1-20,000	1845	...do	159
New Bedford Harbor	...do	1-20,000	1845	...do	158
Buzzard's Bay and Martha's Vineyard Sound	...do	1-20,000	1845	G. S. Blake and C. H. Davis, U. S. N.	163
Sow and Pigs Reef (off Cuttyhunk)	...do	1-5,000	1853	M. Woodhull, U. S. N.	357
Sow and Pigs Reef	...do	1-120	1853	...do	358
Sippican Harbor (sheet No. 1, west)	...do	1-5,000	1863	H. Mitchell	826
Sippican Harbor (sheet No. 2, east)	...do	1-5,000	1863	...do	829
From Mishaum Point to East Rock	Massachusetts and Rhode Island.	1-20,000	1844	G. S. Blake, U. S. N.	154
Westport Harbor, Mass., and coast westward	...do	1-10,000	1844	...do	155
Block Island, Cuttyhunk, and Gay Head (off shore)	...do	1-20,000	1847-'8	R. Bache and J. R. Goldsborough, U. S. N.	204
No Man's Land (off-shore soundings)	...do	1-40,000	1851	C. H. McBlair, U. S. N.	238
Off Point Judith and No Man's Land	...do	1-100,000	1851	S. Swartwout, U. S. N.	2-3
Warren River	Rhode Island	1-5,000	1865-'6	F. P. Webber	886
Seekonk River	...do	1-5,000	1865	A. M. Harrison	865
Narragansett Bay	...do	1-20,000	1861	W. P. Trowbridge	792 a
Taunton River	...do	1-10,000	1862	...do	792 b
Narragansett Bay	...do	1-20,000	1862	H. Mitchell	787
Narragansett Bay, from Quonset Point to Dutch Island	...do	1-10,000	1868	F. P. Webber	992
Narragansett Bay, from Hope Island to Patience Island	...do	1-10,000	1867-'8	...do	939
Greenwich Bay	...do	1-5,000	1867	...do	940
Narragansett Bay, head of, and Providence River	...do	1-10,000	1865-'7	...do	880
Providence River, from city of Providence to Stargut Island.	...do	1-5,000	1865	...do	878
Dutch Island Harbor	...do	1-10,000	1862	H. Mitchell	786
Coaster's Harbor	...do	1-10,000	1863-'5	H. Mitchell and F. P. Webber	785
Newport Harbor	...do	1-5,000	1865	F. P. Webber	811
Saughkonnet River and vicinity	...do	1-10,000	1848	J. R. Goldsborough, U. S. N.	205
From East Rock to Point Judith	...do	1-20,000	1844	G. S. Blake, U. S. N.	153
Point Judith and eastward (off shore)	...do	1-20,000	1847-'8	R. Bache and J. R. Goldsborough, U. S. N.	206
Point Judith and southward to Block Island	...do	1-40,000	1845	G. S. Blake, U. S. N.	162
Block Island Sound, Point Judith to Quonacutog	...do	1-20,000	1839	T. R. Gedney, U. S. N.	84
Block Island and Fisher's Island to Quonacutog	...do	1-20,000	1839	...do	86

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Additional soundings off Montauk Point, Great Eastern Rock.	Rhode Island	1-20,000	1863	T. S. Phelps, U. S. N	780
Pawcatuck River, near Stonington......................	Connecticut.......	1-10,000	1839	....	98
Watch Hill Reef, Block Island Sound..................	....do	1-20,000	1847	C. P. Patterson, U. S. N ...	85
From Gull Island to Watch Hill, Block Island Sound..	....do	1-10,000	1839	T. R. Gedney, U. S. N......	91
Fisher's Island Sound................................	....do	1-10,000	1839	G. S. Blake, U. S. N........	99
Long Island Sound, vicinity of Fisher's Island........	....do	1-10,000	1839	.....do	97
Fisher's Island Sound................................	....do	1-20,000	1839	.....do	96
Thames' Ferry, Long Island Sound	....do	1-10,000	1841	.....do	115
Thames' River, from Gale's Ferry to New London	....do	1-10,000	1839	.....do	114
Thames River, near New London	....do	1-1,200	1869	Charles Junken..........	1006
Thames River, naval station to Norwich..............	...do	1-10,000	1874	H. G. Ogden..............	1242
From Block Point to New London Harbor	....do	1-10,000	1839	G. S. Blake, U. S. N........	92
New London Harbor, Long Island Sound	....do	1-10,000	1839	....	93
Frank's Ledge, off New London Harbor................	....do	1-10,000	1847	Richard Bache, U. S. N ...	94
From Griswold's to Black Point, Long Island Sound...	....do	1-10,000	1838	G. S. Blake, U. S. N	42
Connecticut River (resurvey)	....do	1-10,000	1849	J. R. Goldsborough, U. S. N	233
Connecticut River	....do	1-10,000	1851	M. Woodhull, U. S. N......	276
Connecticut River Bar................................	....do	1-20,000	1851	.....do	275
From Fisherman's Crutch southward, Long Island Sound	....do	1-10,000	1838	G. S. Blake, U. S. N	41
Hammonasset to Cormorant Point	.. do	1-20,000	1838	.....do	39
Tuck's Island and vicinity of Madison, Long Island Sound.	....do	1-10,000	1838	......do	38
From Bartlett to Tuck's Island	...do	1-10,000	1838	......do	37
West Branton and vicinity of Hoadley and Hammonasset.	....do	1-20,000	1838	......do	35
From Stratford light-house to Indian Neck	....do	1-20,000	1838	......do	29
From Saltall to Hoadley, Long Island Sound..........	....do	1-10,000	1838	......do	34
From Oyster River Point to Saltall, abreast of New Haven.	....do	1-10,000	1838	......do	32
Shoal off New Haven light-house	....do	1-5,000	1858	W. G. Temple, U. S. N. ..	647
New Haven Harbor....................................	....do	1-10,000	1872	R. M. Bache..............	1170
Quinnipiack River at Fair Haven......................	....do	1-10,000	1838	....	33
From Charles Island to Oyster River Point	....do	1-10,000	1838	G. S. Blake, U. S. N.......	28
From Black Rock to Charles Island	....do	1-20,000	1837	......do	24
From Charles Island to Black Rock..................	....do	1-10,000	1837	......do	23
Vicinity of Bridgeport, Long Island Sound............	...do	1-5,000	....	....	25
From Sheffield Island light to Black Rock............	....do	1-10,000	1835	G. S. Blake, U. S. N.......	18
From Black Rock to Frost Point......................	....do	1-10,000	....	....	20
From Frost Point to Sheffield Island light............	....do	1-10,000	....	....	19
From Sheffield Island light to Greenwich Point.......	....do	1-10,000	....	....	9
From Greenwich Point to Sheffield light..............	....do	1-10,000	1836	G. S. Blake, U. S. N.......	8
General chart between Gay Head and Cape Henlopen	New York, New Jersey, Delaware.	1-400,000	1859	A. Boschke	670
Montauk Point, Plum Island, and vicinity............	New York	1-10,000	1845	C. H. Davis, U. S. N	88
Plum Island, Montauk Point, and vicinity..........	....do	1-10,000	1845	......do	89
From Fisher's Island to Plum Point, Long Island	....do	1-20,000	1839	......do	87
From Race Point (Fisher's Island) to Oyster Point, Long Island Sound.	....do	1-10,000	1839	G. S. Blake, U. S. N.......	95
Gardner's Bay, Long Island Sound....................	....do	1-20,000	1838	T. R. Gedney, U. S. N.......	80
Bedford Reef. (See Nos. 87, 88, and 95)................	....do	1-10,000	1847	....	90
From Plum Island to Brown's Hill, Long Island Sound	....do	1-10,000	1838	G. S. Blake, U. S. N........	43
From Brown's Hill to Manor light, Long Island Sound.	....do	1-20,000	1838	......do	40
Orient Bay, Long Island Sound........................	....do	1-10,000	1839	T. R. Gedney, U. S. N......	81
Southhold and Orient Bays, and Greenport Harbor.....	....do	1-10,000	1838	......do	78
Greenport Harbor, Long Island Sound	....do	1-10,000	1838	......do	79
Sag Harbor, eastern end of Long Island..............	....do	1-10,000	1839	......do	82
Sag Harbor and vicinity	....do	1-10,000	1839	......do	83
Great and Little Peconic Bays, Long Island...........	....do	1-20,000	....	......do	77
From Single Bull Station to Glover, Long Island Sound.	....do	1-20,000	1838	G. S. Blake, U. S. N........	36
From Glover to Old Point, Long Island Sound..........	....do	1-20,000	1838	......do	30
From Old Point to Miller's Place, Long Island Sound...	....do	1-10,000	1838	......do	31
From Old Point to Eaton Point, Long Island Sound....	....do	1-20,000	1837	......do	21

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
From Eaton Point to Oak Neck, Long Island Sound	New York	1-10,000			10
From Smithtown to Oldfield Point, Long Island Sound	...do	1-10,000	1837	G. S. Blake, U. S. N	26
Hempstead Harbor	...do	1-10,000	1859	T. B. Huger, U. S. N	692
Stony Brook and vicinity, Long Island	...do	1-10,000		G. S. Blake, U. S. N	27
From Smithtown to Eaton Point, Long Island Sound	...do	1-10,000	1837	....do	22
Cow Harbor, Long Island Sound	...do	1-10,000			15
Cow Harbor, Long Island Sound. (See No. 15)	...do	1-3,333			16
Huntington Harbor, Long Island	...do	1-10,000			17
Oyster Bay and Cold Spring Harbor, Long Island	...do	1-3,333			14
Cold Spring Harbor and Oyster Bay, Long Island	...do	1-3,333			13
Oyster Bay and Cold Spring Harbor	...do	1-10,000			11
Oyster Bay and Cold Spring Harbor (duplicate)	...do	1-10,000			12
Whortleberry Island to Greenwich Point, Long Island Sound.	...do	1-10,000	1836-'7	G. S. Blake, U. S. N	4
From Minnrsen Island to Greenwich Point, Long Island Sound.	...do	1-10,000	1836-'7	......do	6
From Captain's Island to Whortleberry Island	...do	1-10,000	1836-'7	......do	5
From Sand light to Matinicock, Long Island Sound	...do	1-10,000	1836-'7	......do	7
Throg's Neck and Davenport Point, Long Island Sound	...do	1-10,000	1837	......do	1
Hewlet's Point to Whortleberry Island, Long Island Sound.	...do	1-10,000			2
Matinicock Point and Throg's Neck, Long Island Sound	...do	1-10,000	1837	G. S. Blake, U. S. N	3
East River, Flushing Bay and vicinity	...do	1-10,000	1841	G. M. Bache, U. S. N	67
Harlem River and Little Hell Gate	...do	1-2,500	1849	M. Woodhull, U. S. N	225
Hell Gate (resurvey)	...do	1-2,500	1848	D. D. Porter, U. S. N	224
East River, from Hell Gate to Throg's Neck, Long Island Sound.	...do	1-10,000	1856	T. A. Craven, U. S. N	580
Harlem River and Spuyten Duyvel Creek	...do	1-10,000	1856	......do	646
East River, from south end of Blackwell's Island to Harlem River.	...do	1-5,000	1856	......do	645
Frying Pan and Pot Rock (Hell Gate)	...do	1-1,280	1866	W. S. Edwards	896
Wallabout Bay (East River)	...do	1-1,250	1869	F. F. Nes	1065
Baltic Rock, New York Harbor	...do	1-2,500	1861	T. S. Phelps, U. S. N	748
Diamond Reef, New York Harbor	...do	1-5,000	1859	J. Wilkinson, U. S. N	698
Coenties Reef and Diamond Reef, New York Harbor	...do	1-2,000	1855	T. A. Craven, U. S. N	497
Diamond Reef and Prince's Reef, New York Harbor	...do	1-2,500	1849	M. Woodhull, U. S. N	226
Off the Battery, New York Harbor	...do	1-5,000	1859	T. A. Craven, U. S. N	678
Off the Battery, New York Harbor	...do	1-5,000	1859	J. Wilkinson, U. S. N	697
Off the Battery, New York Harbor	...do	1-2,500	1867	W. S. Edwards	910
New York Harbor (vicinity of city)	...do	1-10,000	1854	M. Woodhull, U. S. N	460
New York Harbor	...do	1-10,000	1855	T. A. Craven, U. S. N	490
From Jersey City to Williamsburgh, New York Harbor	...do	1-10,000	1855	......do	491 a b
Off Nineteenth street, New York City, East River	...do	1-10,000	1873	F. F. Nes	491 c
From Governor's Island to Blackwell's Island, East River.	...do	1-10,000	1837	T. R. Gedney, U. S. N	66
Buttermilk Channel, New York Bay	...do	1-5,000	1848	D. D. Porter, U. S. N	208
Communipaw Flats, Gowanus Bay, and Buttermilk Channel.	...do	1-10,000	1841	G. M. Bache, U. S. N	130
New York Bay, between Governor's Island and Robbins's Reef.	...do	1-10,000	1868	F. H. Gerdes	970
Additional soundings in New York Bay	...do	1-10,000	1863	T. S. Phelps, U. S. N	783
Gowanus Bay	...do	1-10,000	1872-'3	F. F. Nes	1180
The Narrows, entrance to New York Harbor	...do	1-10,000		T. R. Gedney, U. S. N	63
New York Bay, The Narrows	...do	1-10,000	1872	F. F. Nes	1175
New Jersey Flats and Governor's Island Shoals, New York Lower Bay.	...do	1-10,000	1871-'2	L. H. Marindin	1145 a b
New York Lower Bay	...do	1-20,000	1873	F. F. Nes	1189
Swash Channel, examination of	...do	1-20,000	1866	W. S. Edwards	897 a
New York Lower Bay	...do	1-20,000	1872	F. F. Nes	897 b
Romer and Flynn Shoals, and Swash Channels	...do	1-20,000	1853	M. Woodhull, U. S. N	356
Main channel between Sandy Hook and Flynn's Knoll, and Scotland Shoal.	...do	1-20,000	1869	F. F. Nes	1011
From Fort Hamilton to Sandy Hook, New York Harbor	...do	1-20,000	1855	T. A. Craven, U. S. N	526

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Rockaway and vicinity of Coney Island	New York	1-20, 000			56
Gravesend Bay and vicinity of Coney Island	...do	1-20, 000	1841	G. M. Bache, R. C. Walsh, U. S. N.	59
Vicinity of Coney Island and Rockaway	...do	1-10, 000			57
Gedney's Channel, verification chart	...do	Large scale			55
Gravesend Bay	...do	1-10, 000	1841	G. M Bache, U. S. N.	128
South coast of Long Island	...do	1-40, 000	1850	M. Woodhull, U. S. N.	232
From Montauk Point to Quogue	...do	1-40, 000	1838	T. R. Gedney, U. S. N.	76
From Quogue to Montauk Point	...do	1-20, 000	1838	.....do	74
From Montauk Point to Quogue	...do	1-20, 000	1838	.....do	75
South side of Long Island, vicinity of Quogue	...do	1-40, 000	1838	.....do	73
South side of Long Island, vicinity of Quogue	...do	1-20, 000	1838	.....do	72
From Gilgo Inlet to Quogue, off-shore soundings	...do	1-40, 000	1848	R. Bache, U. S. N.	203
From Smith's Point to Fire Island, east base	...do	1-20, 000	1835	T. R. Gedney, U. S. N.	46
Great South Bay, eastern part	...do	1-10, 000	1834	.....do	44
Great South Bay, western part	...do	1-20, 000	1834	.....do	45
Fire Island Inlet and part of Great South Bay	...do	1-20, 000	1873	Charles Hosmer	1198
From Fire Island Inlet, westward, south shore Long Island	...do	1-10, 000	1834-'5	T. R. Gedney, U. S. N.	48
South side Long Island, from Fire Island to Coney Island	...do	1-40, 000	1835	.....do	47
Gilgo Inlet, south side of Long Island	...do	1-10, 000	1835	.....do	49
New Inlet and Great South Bay	...do	1-10, 000	1835	.....do	50
From Rockaway to Sandy Hook, off-shore soundings	...do	1-20, 000	1835	.....do	51
Rockaway Inlet and part of Jamaica Bay	...do	1-10, 000	1841	G. M. Bache, U. S. N.	129
Hudson River, from Jersey City to Fort Washington	...do	1-5, 000	1837	T. R. Gedney, U. S. N.	70
Hudson River, from Jersey City to Fort Washington	...do	1-10, 000	1837	.....do	71
Hudson River, from Fort Washington northward	...do	1-10, 000	1855	R. Wainwright, U. S. N.	475
Hudson River, from Castle Garden northward	...do	1-10, 000	1855	.....do	477
Hudson River, from the Battery to Thirty-fourth street	...do	1-10, 000	1873	H. L. Marindin	1181
Hudson River, from Sixtieth street, New York City, to Tubby Hook.	...do	1-10, 000	1855	R. Wainwright, U. S. N.	496
Hudson River, from Becker's Landing to Pollock's Point	...do	1-5, 000	1837	T. R. Gedney, U. S. N.	68
Hudson River, from Becker's Landing to Pollock's Point	...do	1-5, 000	1837	.....do	69
Hudson River	...do	1-10, 000	1853	R. Wainwright, U. S. N.	408
Hudson River	...do	1-10, 000	1854	.....do	409
Hudson River	...do	1-10, 000	1854	.....do	410
Hudson River, from Toller's Point to Peekskill	...do	1-10, 000	1854	.....do	458
Hudson River	...do	1-10, 000	1854	.....do	459
Hudson River, from Ft. Montgomery to Buttermilk Hill	...do	1-5, 000	1857	James H. Moore, U. S. N.	630
Hudson River, from Buttermilk Hill to Stony Point	...do	1-5, 000	1857	.....do	631
Hudson River, from Stony Point to Whortleberry	...do	1-10, 000	1857	.....do	632
Hudson River, from New Baltimore to Albany	...do	1-5, 000	1856	R. Wainwright, U. S. N.	549
Hudson River, from Albany to Troy	...do	1-10, 000	1863	A. Strausz	843
Hudson River, from Newburgh to Barnegat	...do	1-10, 000	1859	C. M. Fauntleroy, U. S. N.	729
Hudson River, from Barnegat to Poughkeepsie	...do	1-10, 000	1859	.....do	730
Hudson River, from Poughkeepsie to Pell Island	...do	1-10, 000	1860	.....do	735
Hudson River, from Pell Island to Rhinebeck	...do	1-10, 000	1860	.....do	736
Hudson River, from Rhine Cliff to Glasco	...do	1-10, 000	1861	J. Mechan	752
Hudson River, from Glasco to Tivoli	...do	1-10, 000	1861	.....do	753
Hudson River, from Esopus Creek to Puddecart Point	...do	1-10, 000	1862	.....do	798
Hudson River, from Puddecart Point to Brandon Point	...do	1-10, 000	1862	.....do	799
Hudson River, from Brandon Point to Coxsackie	...do	1-10, 000	1862	.....do	800
Hudson River, from Coxsackie to Houghtailing Island	...do	1-10, 000	1863	A. Strausz	844
Rondout Creek	...do	1-5, 000	1858	A. Murray, U. S. N.	665
Rondout Harbor, from entrance to Sleight's Ferry	...do	1-2, 500	1868	F. H. Gerdes and F. F. Nes	979
Rondout Harbor, from Sleight's Ferry to entrance of Delaware and Hudson Canal.	...do	1-2, 500	1868	.....do	978
Esopus Creek	...do	1-5, 000	1858	A. Murray, U. S. N.	666
Lake Champlain, from Cumberland Head to Valcour Island.	...do	1-20, 000	1870	Charles Junken	1058
Lake Champlain, from Valcour Island to Trembleau Point.	...do	1-20, 000	1871	F. D. Granger	1118a
Lake Champlain, Colchester and Hogsback Reefs	...do	1-10, 000	1871	.....do	1118b
Lake Champlain, from Trembleau Point to Ligonier Point.	...do	1-20, 000	1871	.....do	1119

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Lake Champlain, from Cumberland headlight to Isle La Motte light.	New York and Vermont.	1-20, 000	1872	Charles Junken	1151
Lake Champlain, from Sand Bar Bridge to Butler's Island.	...do	1-20, 000	1872	L. B. Wright	1162
Lake Champlain, from Butler's Island to Canada boundary.	...do	1-20, 000	1873	Charles Junken	1182
Lake Champlain, from Canada boundary to Isle La Motte light.	...do	1-10, 000	1872	.....do	1173
Lake Champlain, from Brothers to Rock Harbor } Lake Champlain, from Crown Point to Rock Harbor. }	...do	1-20, 000	1873	L. B. Wright	1244 *a b*
Jersey Flats, New York Harbor	New Jersey	1-10, 000	1853	M. Woodhull, U. S. N	423
Hackensack River	...do	1-10, 000	1841	G. M. Bache, U. S. N	131
Bar at mouth of Passaic River	...do	1-5, 000	....	T. R. Gedney, U. S. N	65
Passaic River	...do	1-5, 000	1871	F. H. Gerdes	1167
Newark Bay	...do	1-5, 000	1871-'2	.....do	1166 *a*
Newark Bay	...do	1-10, 000	1872	.....do	1166 *b*
Newark Bay	...do	1-10, 000	1855	R. Wainwright, U. S. N	493
Newark Bay	...do	1-10, 000	1855-'6	.....do	547
Kill van Kull	...do	1-10, 000	1855	.....do	492
Newark Bay, Kill van Kull, and Raritan Bay	...do	1-10, 000	....	T. R. Gedney, U. S. N	61
Raritan Bay and Newark Bay	...do	1-20, 000	1836	.....do	62
Staten Island Sound and part of Raritan Bay	...do	1-10, 000	1841	G. M. Bache, U. S. N	127
Arthur Kill, vicinity of Elizabethport	...do	1-10, 000	1855	R. Wainwright, U. S. N	494
Staten Island Sound	...do	1-10, 000	....	T. R. Gedney, U. S. N	64
Arthur Kill, vicinity of Perth Amboy	...do	1-10, 000	1855	R. Wainwright, U. S. N	495
Raritan River (shore-lines with hydrography)	...do	1-5, 000	1872	F. H. Gerdes	1172
Raritan River, from Marsh Island to New Brunswick	...do	1-5, 000	1873	.....do	1204
South River	...do	1-5, 000	1873	.....do	1205
Raritan Bay	...do	1-20, 000	1857	T. A. Craven, U. S. N	572
Raritan Bay, Amboy to Sandy Hook	...do	1-10, 000	1841	G. M. Bache, U. S. N	126
Middletown Creek, Raritan Bay	...do	1-10, 000	1841	.....do	58
Shrewsbury River	...do	1-10, 000	1840	.....do	60
Shrewsbury River	...do	1-10, 000	1840	.....do	107
Main channel between Sandy Hook and Flynn's Knoll and Scotland Shoal.	...do	1-20, 000	1869	F. F. Nes	1009
Sandy Hook Bar	...do	1-10, 000	1835	T. R. Gedney	52
Sandy Hook Bar	...do	1-10, 000	1835	.....do	53
Sandy Hook to Rockaway (old and new channels)	...do	1-20, 000	1840	.....do	54
Sandy Hook and vicinity (resurvey)	...do	1-10, 000	1848	R. Bache, U. S. N	207
Examination of False Hook	...do	1-20, 000	1860	A. Murray, U. S. N	769
Sandy Point (resurvey)	...do	1-5, 000	1863	H. Mitchell	784 *a*
Sandy Hook (resurvey of end)	...do	1-5, 000	1873	F. F. Nes	784 *b*
From Sandy Hook to Barnegat (outer coast)	...do	1-40, 000	1840	T. R. Gedney, U. S. N	106
From Highland light to Long Branch	...do	1-20, 000	1840	.....do	103
From Long Branch to Barnegat	...do	1-20, 000	1840	.....do	102
From Long Branch to Barnegat	...do	1-20, 000	1847	.....do	113
From Long Branch to Metiticonk	...do	1-20, 000	....	.....do	104
From Long Branch to Cape May	...do	1-40, 000	....	.....do	116
From Jones's to Barnegat	...do	1-20, 000	....	.....do	105
Barnegat Inlet	...do	1-10, 000	1866	C. Fendall	883
Barnegat Bay and Inlet and Toms River	.. do	1-10, 000	1840	G. M. Bache, U. S. N	108
From Barnegat to Little Egg Harbor	...do	1-20, 000	1841	T. R. Gedney, U. S. N	111
Little Egg Harbor	...do	1-10, 000	1873	W. I. Vinal	1197 *a*
Barnegat Bay	...do	1-20, 000	1874	.....do	1197 *b*
Little Egg Harbor	...do	1-10, 000	1873	.....do	1196
Little Egg Harbor	...do	1-10, 000	1840	G. M. Bache, U. S. N	109
Little Egg Harbor	...do	1-10, 000	1840	.....do	110
New Inlet to Little Egg Harbor	...do	1-10, 000	1872	W. I. Vinal	1158 *a*
New Inlet to Little Egg Harbor	...do	1-10, 000	1874	.....do	1158 *b*
Great Bay	...do	1-10, 000	1871	W. W. Harding	1125
Mullicus River	...do	1-10, 000	1872	W. I. Vinal	1159
Brigantine Inlet	...do	1-10, 000	1872	.....do	1165
Absecom Inlet and adjacent waters	...do	1-10, 000	1871-'2	.....do	1160

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Absecom Inlet	New Jersey	1-10, 000	1864	T. S. Phelps, U. S. N	637
Coast of New Jersey	...do	1-40, 000	1847	T. R. Gedney, U. S. N	112
Additional soundings off the coast of New Jersey	...do	1-200, 000	1861	T. S. Phelps, U. S. N	749
Off Delaware Bay and Capes May and Henlopen	... do	1-40, 000	1847	T. R. Gedney, U. S. N	117
From Cape May to Montauk, N. Y	New Jersey and New York.	1-400, 000	1842	......do	100
From Cape May to Montauk, N. Y	...do	1-400, 000	1842-'4-'7	......do	101
Back Channel, Schuylkill and Delaware Rivers, League Island.	Pennsylvania	1-2, 500	1865	E. Hergesheimer	862
Schuylkill River, League Island to Gray's Ferry	...do	1-5, 000	1871	F. F. Nes	1200 *a*
Schuylkill River, Gray's Ferry to Suspension Bridge	...do	1-5, 000	1871	......do	1200
Off Cape May and Cape Henlopen	Delaware and New Jersey.	1-40, 000	1844	G. M. Bache, U. S. N	151
Delaware Bay, and river up to Trenton	...do	1-80, 000	1841-'2-'3	G. S. Blake, U. S. N	148
Delaware Bay, Overfalls, north and south shoals	... do	1-20, 000	1847	R. Bache, U. S. N	125
Delaware Bay, Breakwater	...do	1-5, 000	1863	C. P. Patterson, hydrographic inspector.	801
Delaware Bay, Cape May Roads and Crow Shoals	...do	1-10, 000	1847	R. Bache, U. S. N	157
Delaware Bay, Crow Shoals	...do	1-10, 000		G. S. Blake, U. S. N	120
Delaware Bay, Fishing Creek and vicinity	...do	1-10, 000	1842	......do	123
Delaware Bay, Capes May and Henlopen to Fishing Creek and Mispillion.	...do	1-20, 000	1842-'3	......do	118
Delaware Bay, Capes May and Henlopen to Mispillion	...do	1-20, 000	1842	......do	119
Delaware Bay, Clark's Point and vicinity	...do	1-20, 000	1842	......do	122
Delaware Bay, Maurice, Cohancy, and Duck Rivers	...do	1-20, 000	1843	......do	121
Delaware Bay, from Egg Island light to Davis Point	...do	1-20, 000	1841	......do	124
Delaware Bay, Joe Flogger Shoal and Dona River	...do	1-20, 000	1852	M. Woodhull, U. S. N	299
Delaware Bay, Dona and Mahon Rivers	...do	1-10, 000	1852	......do	352
Delaware Bay, from Ben Davis Point to Liston's Tree	...do	1-10, 000	1841	G. S. Blake, U. S. N	132
Delaware Bay, from Liston's Tree to Newcastle	...do	1-10, 000	1840-'1	......do	133
Delaware Bay, from Newcastle to Liston's Tree (resurvey).	...do	1-20, 000	1843	......do	134
Delaware Bay, from Newcastle to Reedy Point	...do	1-10, 000	1861	G. Davidson	808
Delaware Bay, Bulkhead Shoals	...do	1-10, 000	1846-'7	J. R. Goldsborough, U. S. N., W. P. McArthur, U. S. N.	156
Delaware River, river front of Newcastle	...do	1-1, 250	1873	Charles Junken	1183 *a b*
Delaware River, from Newcastle to Dupont's Wharf	...do	1-10, 000	1841	G. S. Blake, U. S. N	135
Delaware River, from Dupont's Wharf to Newcastle (duplicate).	...do	1-10, 000	1841	......do	136
Delaware River, Christiana Creek	...do	1-5, 000	1841	......do	137
Delaware River, from Dupont's Wharf to Tonkins Island.	...do	1-10, 000	1842	......do	138
Delaware River, from Tonkins Island to Upper Tinicum.	Delaware and Pennsylvania.	1-10, 000	1842	......do	139
Delaware River, from Upper Tinicum to Fort Mifflin	Pennsylvania and New Jersey.	1-5, 000	1842	......do	140
Delaware River, from Fort Mifflin to Philadelphia	...do	1-10, 000	1843	......do	141
Delaware River, from Fort Mifflin to Gloucester Point } Delaware River, from Gloucester Point to Navy Yard }	...do	1-5, 000	1871	F. F. Nes	1114 *a b*
Delaware River, from Riley's Creek to Walsh Street Wharf.	...do	1-1, 200	1870	Charles Junken	1057 *a*
Delaware River, from Walsh Street Wharf to Carson Wharf.	...do	1-1, 200	1870	......do	1057 *b*
Delaware River, from Philadelphia to Bridesburg	...do	1-10, 000	1843	G. S. Blake, U. S. N	142
Delaware River, opposite Philadelphia	...do	1-5, 000	1843	......do	143
Delaware River, from Bridesburg to Dunks	...do	1-10, 000	1844	......do	144
Delaware River, from Dunks to Smith's	...do	1-10, 000	1844	......do	145
Delaware River, from Smith's to Shives	...do	1-10, 000	1844	......do	146
Delaware River, from Bordentown to Trenton	...do	1-10, 000	1844	......do	147
Off Cape Henlopen	Delaware	1-200, 000	1847	S. P. Lee, U. S. N	189
Hen and Chicken Shoals	...do	1-20, 000	1847	......do	152
From Cape Henlopen to Indian River Inlet	...do	1-20, 000	1844	G. M. Bache, U. S. N	149
Off Cape Henlopen and southward to Cape Henry	...do	1-40, 000	1849-'50	T. A. Jenkins, U. S. N	237

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Indian River and Rehoboth Bay	Delaware	1-20,000	1847	R. Bache, U. S. N.	150
From Indian River Inlet to Beach House	Delaware and Maryland.	1-40,000	1848	S. P. Lee, U. S. N.	212
From Beach House Station to North Birch	...do	1-40,000	1844	...do	213
Sea-coast of Maryland	Maryland	1-40,000	1850	...do	251
Winterquarter Shoal	...do	1-40,000	1863	T. S. Phelps, U. S. N.	761
Chesapeake Bay, Little and Big Annemessex and Manokin Rivers, Morris Bay, and Wicomico River.	...do	1-20,000	1858-'9	W. T. Muse, U. S. N.	707
Chesapeake Bay, Nanticoke River, and Fishing Bay	...do	1-20,000	1858	...do	673
Chesapeake Bay, Wicomico River, Saint Clement's and Breton's Bays, and Saint George's River.	...do	1-20,000	1860-'8	W. T. Muse, U. S. N., J. W. Donn.	969 a b
Chesapeake Bay, Saint Mary's River from Point Lookout to Ford's Landing.	...do	1-20,000	1857	W. T. Muse, U. S. N.	610
Chesapeake Bay, Saint Mary's River, mouth and approaches.	...do	1-20,000	1859-'60	...do	701
Chesapeake Bay, Saint Mary's River	...do	1-20,000	1859	...do	695
Chesapeake Bay, from Cove Point to Point No-Point, and entrance to Patuxent River.	...do	1-20,000	1848	S. P. Lee, U. S. N.	209
Chesapeake Bay, Patuxent River, from entrance to Saint Leonard's Creek.	...do	1-20,000	1848	...do	210
Chesapeake Bay, Patuxent River, from Holland's Point No. 2 to Jones's Point.	...do	1-20,000	1859	W. T. Muse, U. S. N.	704
Chesapeake Bay, Patuxent River	...do	1-20,000	1857	...do	641
Chesapeake Bay, Meekin's Neck, and vicinity of Cove Point.	...do	1-20,000	1847-'8	W. P. McArthur, U. S. N.	199
Chesapeake Bay, Little Choptank River	...do	1-20,000	1848	...do	200
Chesapeake Bay, Choptank River	...do	1-20,000	1848	...do	202
Chesapeake Bay, Choptank River	...do	1-20,000	1848	...do	201
Chesapeake Bay, Choptank River, from Wing's Landing to Denton.	...do	1-10,000	1870	W. W. Harding	1048
Chesapeake Bay, tributaries to Tredhaven Creek	...do	1-10,000	1870	...do	1049 a
Chesapeake Bay, heads of Harris, Broad, and Porter's Creeks.	...do	1-10,000	1870	...do	1049 b
Chesapeake Bay, tributaries of Wye River	...do	1-10,000	1870	...do	1050 a
Chesapeake Bay, tributaries of Saint Michael's River	...do	1-10,000	1870	...do	1050 b
Chesapeake Bay, Eastern Bay, and Wye and Miles Rivers.	...do	1-20,000	1847	W. P. McArthur, U. S. N.	177
Chesapeake Bay, Thomas' Point to Tilghman's Island	...do	1-20,000	1846	S. P. Lee, U. S. N.	188
Chesapeake Bay, Annapolis Harbor	...do	1-20,000	1844	G. M. Bache, U. S. N.	167
Chesapeake Bay, head of Severn River	...do	1-20,000	1870	W. W. Harding	1077 b
Chesapeake Bay, tributaries of Severn and South Rivers	...do	1-20,000	1870-'1	...do	1077 a
Chesapeake Bay, from Sandy Point to Spy's Stand	...do	1-20,000	1845	G. M. Bache, U. S. N.	166
Chesapeake Bay, Magothy River	...do	1-10,000	1845	...do	164
Chesapeake Bay, mouth of Chester River	...do	1-20,000	1847	W. P. McArthur, U. S. N.	175
Chesapeake Bay, Chester River	...do	1-20,000	1846	...do	174
Chesapeake Bay, Chester River No. 1, and Morgan's Creek.	...do	1-5,000	1869-'70	W. W. Harding	1026 a b
Chesapeake Bay, Chester River No. 2	...do	1-5,000	1869-'70	...do	1027
Chesapeake Bay, Langford Creek	...do	1-10,000	1870	...do	1078
Chesapeake Bay, entrance to Patapsco River	...do	1-20,000	1854	R. Wainwright, U. S. N.	415
Chesapeake Bay, Patapsco River at Baltimore	...do	1-10,000	1845	G. M. Bache, U. S. N.	165
Chesapeake Bay, Patapsco River from Rock Point to Sollers' Point.	...do	1-10,000	1852	C. H. McBlair, U. S. N.	339
Chesapeake Bay, Belvidere Shoals, Patapsco River entrance.	...do	1-5,000 1-20,000	1852	A. Boschke	469
Chesapeake Bay, Patapsco River, mouth of	...do	1-20,000	1866	F. P. Webber	913
Chesapeake Bay, Patapsco River, Brewster's Channel	...do	1-10,000	1866	...do	914
Chesapeake Bay, Patapsco River, Brewster's Channel (enlarged from No. 913).	...do	1-10,000	1866	...do	915
Chesapeake Bay, Patapsco River, creeks emptying into	...do	1-20,000	1869	J. W. Donn	1007
Chesapeake Bay, Gunpowder, Middle, and Back Rivers	...do	1-20,000	1846	W. P. McArthur, U. S. N.	169
Chesapeake Bay, from Howell's Point to Pool's Island	...do	1-10,000	1846	S. P. Lee, U. S. N.	187

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Chesapeake Bay, Bush River	Maryland	1-20,000	1846	W. P. McArthur, U. S. N.	171
Chesapeake Bay, from Turkey Point to Howell's Point	...do	1-10,000	1846	S. P. Lee, U. S. N	186
Chesapeake Bay, Romney, Farley's, Stillpond, Churn, and Loyd's Creeks.	...do	1-10,000	1870	W. W. Harding	1072
Chesapeake Bay, Sassafras River	...do	1-20,000	1847	W. P. McArthur, U. S. N.	176
Chesapeake Bay, Sassafras River	...do	1-10,000	1870	W. W. Harding	1071
Chesapeake Bay, northern part down to Turkey Point	...do	1-10,000	1846	S. P. Lee, U. S. N	185
Chesapeake Bay, Elk River	...do	1-10,000	1846	W. P. McArthur, U. S. N.	172
Chesapeake Bay, Bohemia River and Back Creek	...do	1-10,000	1846	......do	170
Chesapeake Bay, Northeast River	...do	1-10,000	1846	......do	173
Chesapeake Bay, Susquehanna River, mouth of	...do	1-10,000	1867	F. P. Webber	898
Chesapeake Bay, Susquehanna River	...do	1-10,000	1846	W. P. McArthur, U. S. N.	168
Chesapeake Bay, Susquehanna River (duplicate of 168)	...do	1-10,000	1852		326
Eastern Branch of the Potomac, from Anacostia Bridge to Benning's Bridge.	Dist. of Columbia	1-5,000	1865	A. Balbach	863
Eastern Branch, from Benning's Bridge to Bladensburg.	Dist. of Columbia and Maryland.	1-5,000	1865	......do	864
Potomac River, from Alexandria to Hunter's Point	Dist. of Columbia and Virginia.	1-10,000	1862	C. P. Patterson, U. S. N.	766
Potomac River, from Hunter's Point to Long Bridge, and Eastern Branch to Anacostia Bridge.	Dist. of Columbia	1-5,000	1862	......do	764
Potomac River, from Long Bridge to the Aqueduct	...do	1-5,000	1862	......do	765
Potomac River, from Analostan Island to Long Bridge	...do	1-5,000	1867	C. Fendall	1082
Chincoteague Shoals and Chincoteague Inlet	Virginia	1-40,000	1851	J. J. Almy, U. S. N	298
Chincoteague Inlet and Chincoteague Shoals	...do	1-20,000	1851	......do	297
Metomkin Inlet	...do	1-10,000	1852	......do	349
Metomkin Inlet, sea-coast of Virginia	...do	1-20,000	1862	A. M. Harrison	795
Wachapreague Inlet and Hog Island Harbor	...do	1-40,000	1852	J. J. Almy, U. S. N	348
Hog Island Harbor and Wachapreague Inlet	...do	1-20,000	1852	......do	354
Hog Island and vicinity to Cape Henry	...do	1-40,000	1853	......do	397
Little Machipongo, to head of Broadwater	...do	1-20,000	1871	J. W. Donn	1104
Broadwater, Great Machipongo River, and branches	...do	1-20,000	1871	......do	1103
Broadwater, from Sand Shoal Inlet to Hog Island Inlet	...do	1-20,000	1870	W. W. Harding	1070 *b*
Broadwater, from Ship Shoal Inlet to Sand Shoal Inlet	...do	1-20,000	1870	......do	1070 *a*
Sand Shoal Inlet and Ship Shoal Inlet	...do	1-20,000	1853	J. J. Almy, U. S. N	388
Magothy Bay	...do	1-20,000	1869	W. W. Harding	1013
Entrance of Chesapeake Bay	...do	1-20,000	1851	B. F. Sands, U. S. N.	286
Cape Charles and vicinity	...do	1-20,000	1852	J. J. Almy, U. S. N	345
Cape Charles and vicinity of Cherrystone Inlet	...do	1-40,000	1852-'3	......do	364
Cherrystone Inlet, Chesapeake Bay	...do	1-20,000	1852	......do	353
Cherrystone Inlet, Chesapeake Bay	...do	1-10,000	1873	J. S Bradford	1169
Hunger's Creek, Chesapeake Bay	...do	1-20,000	1853	J. J. Almy, U. S. N	368
Hunger's Creek	...do	1-20,000	1868	C. Fendall	976 *c*
Nasswaddox Creek	...do	1-20,000	1868	......do	976 *b*
Occohannock, Craddock, and Nandua Creeks	...do	1-20,000	1868	......do	976 *a*
Occohannock Creek and Heath's Landing	...do	1-20,000	1853	J. J. Almy, U. S. N	367
Pungoteague Creek	...do	1-20,000	1851-'68	B. F. Sands, J. J. Almy, U. S. N.	332
Pocomoke Sound	...do	1-40,000	1855	J. J. Almy, U. S. N	515
Pocomoke Sound, creeks from Messongo Creek to Onancock Creek.	...do	1-20,000	1869	W. W. Harding	993
Pocomoke River, entrance	...do	1-10,000	1869	......do	1004
Pocomoke River, sheets Nos. 1 and 2	...do	1-5,000	1869	......do	1022 *a b*
Pocomoke River, sheets Nos. 3 and 4	...do	1-5,000	1869	......do	1023 *a b*
Pocomoke River, sheets Nos. 5, 6, and 7	...do	1-5,000	1869	......do	1024 *a b c*
Little Annemessex River	...do	1-10,000	1868-'9	......do	985
Smith's, Goose, and Fox Islands, Tangier Sound	...do	1-20,000	1869	......do	997
Tangier Sound	...do	1-40,000	1856	J. J. Almy, U. S. N.	557
From Point No-Point to Smith's Point Light, Chesapeake Bay.	...do	1-20,000	1849	S. P. Lee, U. S. N	211
Reconnaissance of White House and Lower Cedar Points, Potomac River.	...do	1-10,000	1861	W. R. Palmer, U. S. A.	738
Potomac River, from Piney Point to Blakistone Island	...do	1-20,000	1860	W. T. Muse, U. S. N.	793

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Potomac River, from Blakistone to Cob Point	Virginia	1-20, 000	1862	T. S. Phelps, U. S. N.	827
Potomac River, from Cob Point to Mathias Point	...do	1-20, 000	1862	......do	778
Potomac River, from Mathias Point to Metomkin Point	...do	1-20, 000	1862	......do	813
Potomac River, from Metomkin Point to Shipping Point.	...do	1-20, 000	1862	......do	812
Potomac River, from Shipping Point to Hallowing Point	...do	1-20, 000	1862-'3	......do	814
Potomac River, from Hallowing Point to Fort Washington.	...do	1-10, 000	1863	......do	815
Potomac River, from Fort Washington to Alexandria	...do	1-10, 000	1863	......do	816
Nomini Bay, Lower Machodoc, and Mattox Creeks	...do	1-20, 000	1868	J. W. Donn	967
Yeocomico and Coan Creeks	...do	1-20, 000	1868	......do	968
Yeocomico and Coan Creeks	...do	1-20, 000	1860	W. T. Muse, U. S. N.	794
Great Wicomico River	...do	1-20, 000	1869	J. W. Donn	1003
Little Bay, Nantepoison, Tapp's, Dimer's, Indian, Dividing, and Mill Creeks.	...do	1-20, 000	1869	......do	1005
Chesapeake Bay, from Potomac to Rappahannock River.	...do	1-40, 000	1850	S. P. Lee, J. J. Almy, U. S. N	252
Chesapeake Bay, from Rappahannock River to Wolf Trap.	...do	1-40, 000	1851	J. J. Almy, U. S. N.	285
Rappahannock River, entrance	...do	1-10, 000	1857	R. Wainwright, U. S. N.	610
Rappahannock River	...do	1-10, 000	1857	......do	609
Rappahannock River	...do	1-10, 000	1857	......do	608
Rappahannock and Corrotoman River	...do	1-10, 000	1857	.....do	611
Estuaries of the Corrotoman River	...do	1-10, 000	1869	J. W. Donn	1002
Estuaries of the Rappahannock River	...do	1-10, 000 1-20, 000	1869	......do	1001
Bowler's and Corner Rock, Rappahannock River	...do	1-2, 500	1867	.....do	937
Rappahannock River	...do	1-10, 000	1856	R. Wainwright, U. S. N.	607
Rappahannock River	...do	1-10, 000	1856	......do	606
Rappahannock River	...do	1-10, 000	1856	......do	605
Rappahannock River	...do	1-10, 000	1855	......do	523
Rappahannock River	...do	1-10, 000	1855	......do	522
Rappahannock River	...do	1-10, 000	1855	......do	521
Rappahannock River	...do	1-10, 000	1854	......do	454
Rappahannock River to Tobago Bay	...do	1-10, 000	1854	......do	453
Rappahannock River at Port Royal	...do	1-5, 000	1854	......do	452
Rappahannock River	...do	1-5, 000	1854	.....do	451
Rappahannock River	...do	1-5, 000	1854	.....do	450
Rappahannock River	...do	1-5, 000	1853-'4	......do	400
Rappahannock River	...do	1-5, 000	1853-'4	......do	399
Rappahannock River at Fredericksburgh	...do	1-5, 000	1853-'4	.....do	398
Piankatank River	...do	1-20, 000	1869	J. W. Donn	988
Milford Haven (with topography)	...do	1-20, 000	1868-'9	.....do	987
Estuaries of Mobjack Bay	...do	1-20, 000	1868	.....do	984
York River, from entrance to Bigler's Mill	...do	1-20, 000	1857	J. J. Almy, U. S. N	583
York River, from Bigler's Mill to West Point	...do	1-20, 000	1857	R. D. Minor, U. S. N	584
Back and Pocosen Rivers	...do	1-20, 000	1868	C. Fendall, W. W. Harding	977
James River, entrance	...do	1-20, 000	1854-'5	J. N. Maffitt, U. S. N	529
James River, Newport News Point	...do	1-10, 000	1865	E. Hergesheimer	877
James River, Newport News to Point Shoal light-house	...do	1-20, 000	1872	J. W. Donn	1179 a
James River, Burwall Bay to Cobham	...do	1-20, 000	1873	.....do	1179 b
James River, from Jamestown Island to Sandy Point	...do	1-20, 000	1874	.....do	1229
James River, Shoal Point to Jamestown Island	...do	1-20, 000	1855	J. N. Maffitt, U. S. N.	530
James River	...do	1-20, 000	1856	......do	615
James River	...do	1-10, 000	1857	......do	616
James River, from Little Brandon to Wyanoke Wharf (reconnaissance).	...do	1-10, 000	1857	......do	634
James River, from Douthard to Westover West	...do	1-10, 000	1859	W. T. Muse, U. S. N	705
James River, Harrison's Bar	...do	1-10, 000	1852	R. Wainwright, U. S. N.	331
James River	...do	1-5, 000	1853	......do	395
James River	...do	1-5, 000	1853	......do	394
James River	...do	1-5, 000	1853	......do	393

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Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
James River	Virginia	1-5,000	1853	R. Wainwright, U. S. N.	392
James River	...do	1-5,000	1853	......do	391
James River, Trent's Reach Bar	...do	1-5,000	1853	......do	343
James River	.. do	1-5,000	1853	......do	340
James River	...do	1-5,000	1853	......do	390
James River at Warwick Bar	...do	1-5,000	1852-'3	......do	341
James River at Richmond	...do	1-5,000	1852-'3	......do	342
Appomattox River	...do	1-5,000	1852	......do	316
Appomattox River	...do	1-5,000	1852	......do	315
Appomattox River at Petersburg	...do	1-5,000	1852	......do	314
Appomattox River	...do	1-10,000	1851	......do	279
Chickahominy River, lower portion	...do	1-20,000	1874	J. W. Donn	1225 *a*
Chickahominy River, from Ship-Yard Landing to Forge Bridge.	...do	1-20,000	1875	......do	1225 *b*
Nansemond River	...do	1-10,000	1874	R. Platt, U. S. N	1213
Hampton Roads	...do	1-20,000	1873	......do	1188
Elizabeth River, East Branch and Tanner's Creek	...do	1-10,000	1873	......do	1187 *a*
Elizabeth River, Western Branch	...do	1-10,000	1873	......do	1187 *b*
Elizabeth River, from Washington Point to navy-yard.	...do	1-2,500	1866	......do	894
Elizabeth River, Norfolk to navy-yard	...do	1-5,000	1873	......do	1186 *a*
Elizabeth River, Craney Island to Norfolk	...do	1-5,000	1873	......do	1186 *b*
Elizabeth River, South Branch, base-line, to Chesapeake and Albemarle Canal.	...do	1-10,000	1873	......do	1185 *a*
Elizabeth River, navy-yard to base-line	...do	1-10,000	1873	......do	1185 *b*
Elizabeth River at Norfolk	...do	....	....	....	....
Hampton Roads and part of Elizabeth River	...do	1-20,000	1854	J. J. Almy, U. S. N	447
Lynn Haven Roads, Chesapeake Bay	...do	1-10,000	1854	......do	449
From Cape Henry to Mobjack Bay	...do	1-40,000	1854	......do	446
Coast from Cape Henry, southward, to boundary	...do	1-40,000	1855	......do	520
Soundings off False Cape	.. do	1-40,000	1861	T. S. Phelps, U. S. N.	750
Off shore from Cape Henry to Cape Hatteras	Virginia and North Carolina.	1-200,000	1859	A. Murray, U. S. N.	674
Off shore from Cape Henry to Cape Lookout	...do	1-500,000	1860	......do	767
Off shore from Sheephouse Hill to Killdevil Hills	...do	1-40,000	1868	R. Platt, U. S. N	965
Off shore from Killdevil Hills to Loggerhead Inlet	North Carolina	1-40,000	1870	......do	1053
Off shore from Loggerhead Inlet to Cape Hatteras	...do	1-40,000	1869-'70	......do	1056
Off shore from Cape Hatteras to Federal Point	...do	1-240,000	1865-'6	......do	884
Deep-sea soundings from Cape Lookout to Saint Augustine.	...do	1-500,000	1860	A. Murray, U. S. N.	768
Off shore from Cape Hatteras to Cape Fear	...do	1-200,000	1859	......do	686
Coast, from mouth of Cape Fear River to Tubbs' Inlet.	...do	1-40,000	1859	J. P. Bankhead, U. S. N.	685
Currituck Sound	...do	1-20,000	1851	R. Wainwright, U. S. N.	258
Currituck Sound, reconnaissance of head of	...do	1-10,000	1859	J. Mechan	702
North River, head of Currituck Sound, reconnaissance of	.. do	1-20,000	1859	......do	703
North River	...do	1-20,000	1850	R. Wainwright, U. S. N.	230
Pasquotank River, Albemarle Sound	...do	1-20,000	1874	W. P. McArthur, U. S. N	195
Little River	...do	1-20,000	1848	......do	197
Perquimans River	...do	1-20,000	1848	......do	196
Albemarle Sound, Harvey's Creek to Hornblow Point.	...do	1-20,000	1849	James Alden, U. S. N	219
Albemarle Sound, Mackey's Creek to Roanoke River	...do	1-20,000	1849	T. A. Jenkins, U. S. N.	216
Chowan River (2 sheets)	.. do	1-20,000	1874	R. E. Halter	1230 *a b*
Middle, Eastmost, and part of Roanoke River	...do	1-10,000	1864	J. S. Bradford	822
Batchelor's Bay, Albemarle Sound	...do	1-10,000	1864	......do	828
Scuppernong River and Bulls Bay, Albemarle Sound	...do	1-20,000	1849	T. A. Jenkins, U. S. N	217
Albemarle Sound, Mills Point to Pear-tree Point	...do	1-20,000	1848	W. P. McArthur, U. S. N	198
Alligator River, Albemarle Sound	...do	1-20,000	1849	James Alden, U. S. N.	218
Haulover, Albemarle Sound, and vicinity of Powell's Point.	...do	1-20,000	1849	......do	220
Albemarle, Roanoke, and Croatan Sounds	...do	1-20,000	1850-'1	R. Wainwright, U. S. N.	257
Croatan Sound, examination of obstructions in	...do	1-20,000	1861	J. S. Bradford	836
Croatan Sound and Pamplico Sound (2 sheets)	...do	1-20,000	1873	F. F. Nes	1180 *a b*
Pamplico Sound	...do	1-40,000	1858	W. T. Muse, U. S. N	672
Pamplico Sound	...do	1-20,000	1857	......do	661

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Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Pamplico Sound, reconnaissance of Long Shoal	North Carolina	1-10,000	1866	J. S. Bradford	887
Pamplico Sound, Bell's Bay and Juniper Bay	do	1-20,000	1874	F. F. Nes	1226 *a b*
Pamplico Sound, Hog Islands	do	1-40,000	1874	do	1227
Pamplico Sound, from Royal Shoal to Brant Island	do	1-40,000	1866-'69-'70	J. S. Bradford and F. F. Nes	1083
Pamplico Sound, western part	do	1-20,000	1869	F. F. Nes	1010
Pungo River, upper and lower sheets	do	1-20,000	1872	do	1140 *a b*
Pamplico River, from Pamplico light-house to Indian Island.	do	1-20,000	1869-'70	do	1068
Pamplico River, from Adams Point to Rumley Marshes	do	1-20,000	1871	do	1099
Pamplico River, from Rumley Marshes to Ragged Point	do	1-20,000	1871	do	1100
Pamplico River, from Ragged Point to Washington	do	1-20,000	1871	do	1101
Pamplico River, from Cedar Grove to Tar River	do	1-10,000	1872	do	1132
Bay River	do	1-20,000	1869	do	1011
Neuse River from Point of Marsh to Cedar Point	do	1-20,000	1868	J. S. Bradford and F. F. Nes	974
Neuse River, from Cedar Point to Wilkinson's Point	do	1-20,000	1868	J. S. Bradford	963
Neuse River, from Cherry Point to Johnson's Point	do	1-20,000	1867-'8	do	956
Neuse River, from Johnson's Point to Fort Anderson	do	1-10,000	1866	do	892
Neuse River, vicinity of Newbern	do	1-20,000	1863-'4	A. Strausz	845
South River, Turnagain Bay, and other tributaries to Neuse River.	do	1-20,000	1868-'9	J. S. Bradford and F. F. Nes	975
Cedar Island, bay, and vicinity	do	1-20,000	1870	F. F. Nes	1079
Oregon Inlet	do	1-10,000	1862	H. Mitchell	762
Hatteras Shoals	do	1-20,000	1850	T. A. Jenkins, U. S. N.	244
Cape Hatteras Shoals	do	1-20,000	1871-'2	R. Platt, U. S. N	1135
Off-shore Soundings, Hatteras Shoals	do	1-40,000	1871-'2	do	1136
Hatteras Inlet	do	1-10,000	1861	T. S. Phelps, U. S. N	763
Hatteras Inlet	do	1-10,000	1852	R. Wainwright, U. S. N.	322
Hatteras Inlet, (reconnaissance)	do	1-5,000	1850	T. A. Jenkins, U. S. N.	235
Hatteras Inlet	do	1-10,000	1857	W. T. Muse, U. S. N	612
Hatteras Inlet, inner bulkhead	do	1-10,000	1864	A. Strausz	612 *bis.*
Coast, from Cape Hatteras to Ocracoke Inlet	do	1-40,000	1856	J. J. Almy, U. S. N	538
Ocracoke Inlet	do	1-10,000	1852	R. Wainwright, U. S. N.	321
Ocracoke Inlet (resurvey)	do	1-20,000	1857	W. T. Muse, U. S. N	613
The Straits of North Carolina	do	1-20,000	1864	E. Cordell	854
Core Sound, from the Straits to Pamplico Sound	do	1-40,000	1864	do	855
Cape Lookout Shoals (reconnaissance)	do	1-40,000	1861	T. S. Phelps, U. S. N	849
Cape Lookout Shoals	do	1-40,000	1865-'6	R. Platt, U. S. N., and C. Junken.	885
From Cape Lookout toward Bogue Sound	do	1-40,000	1857	C. R. P. Rodgers, U. S. N.	577
Beaufort Harbor and vicinity of Cape Lookout	do	1-10,000	1854	J. N. Maffitt, U. S. N.	419
Beaufort Harbor	do	1-10,000	1850	do	259
Beaufort Harbor and Bar	do	1-10,000	1857	C. R. P. Rodgers, U. S. N.	576
Beaufort Harbor (resurvey)	do	1-10,000	1862	A. Boschke	789
Beaufort Harbor, off Fort Macon	do	1-10,000	1863	A. Strausz	789 *bis.*
Beaufort Harbor	do		1850	J. N. Maffitt, U. S. N.	246
Beaufort Harbor, entrance (resurvey)	do	1-10,000	1864	Ed. Cordell	856
Beaufort Harbor and adjacent waters	do	1-20,000	1874	W. I. Vinal	1219
Newport River and estuaries	do	1-20,000	1874	W. I. Vinal	1203
Bogue Sound, from Carolina City to Beaufort	do	1-10,000	1854	J. N. Maffitt, U. S. N.	418
From Flagstaff to New River Inlet	do	1-40,000	1858-'9	A. Murray, U. S. N	644
New River and bar	do	1-10,000	1851	J. N. Maffitt, U. S. N.	280
New Inlet, Cape Fear entrance (resurvey)	do	1-10,000	1852	do	370
Cape Fear Bar and New Inlet	do	1-10,000	1851	do	278
New Inlet Bar, northern entrance of Cape Fear River	do	1-10,000	1856	do	618
New Inlet, northern entrance of Cape Fear River	do	1-10,000	1858	T. B. Huger, U. S. N.	643
New Inlet Bar, northern entrance of Cape Fear River	do	1-10,000	1857	J. N. Maffitt, U. S. N.	621
New Inlet, entrance to Cape Fear River	do	1-10,000	1865	J. S. Bradford	875
New Inlet, Cape Fear River	do	1-10,000	1872	W. I. Vinal	1134
Cape Fear River	do	1-5,000	1852	J. N. Maffitt, U. S. N.	375
Cape Fear River	do		1853	do	416
Cape Fear River	do	1-10,000	1853	do	374
Cape Fear River Bar	do		1852	do	372
Cape Fear River Bar	do	1-10,000	1858	T. B. Huger, U. S. N.	642

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Cape Fear River entrance, bars of Oak Island and Bald Head Channel.	North Carolina...	1-5, 000	1871	Charles Junken...........	1089
Cape Fear River entrance	.. do	1-10, 000	1865	J. S. Bradford	870
Cape Fear River, between Forts Creswell and Johnson	.. do	1-10, 000	1866	......do	876
Cape Fear River, western entrance	..do	1-10, 000	1872	W. I. Vinal	1128 a
Cape Fear River, western entrance....................	.. do	1-10, 000	1874	.....do	1128 b
Cape Fear River, resurvey of Seward Channel, western entrance.	....do	1-10, 000	1873	......do	1190 a
Cape Fear River, Drum Shoal to Ballast Rock.........	...do	1-10, 000	1873	......do	1190 b
Cape Fear River, Ballast Rock to Alligator Creek......	....do	1-10, 000	1873	......do	1191 a
Cape Fear River, Alligator Creek to Wilmington	.. do	1-10, 000	1873	......do	1191 b
Cape Fear River, inner bar............................	.. do	1-10, 000	1870	F. F. Nes...................	1014
Cape Fear River, southern bars of.....................	....do	1-10, 000	1856	J. N. Maffitt, U. S. N......	619
Cape Fear River, southern bars of....................	.. do	1-10, 000	1857	......do	624
Frying Pan Shoals....................................	.. do	1-20, 000	1851	T. A. Jenkins, U. S. N	306
Frying Pan Shoals....................................	...do	1-20, 000	1851	......do	277
Off-shore soundings from Cape Fear to Charleston Harbor.	North and South Carolina.	1-300, 000	1859	J. P. Bankhead, U. S. N....	694
Georgetown Harbor and Bar...........................	South Carolina....	1-10, 000	1853	J. N. Maffitt, U. S. N......	371
Winyah Bay and Georgetown Harbor...................	.. do	1-10, 000	1853	.....do	373
Georgetown Bar (resurvey)...........................	.. do	1-20, 000	1856	......do	533
Santee Rivers, upper and middle sheets	...do	1-10, 000	1873	W. H. Dennis	1193 a b
Santee Rivers, lower sheet	...do	1-10, 000	1873	......do	1194
Cape Romain..	.. do	1-20, 000	1852	T. A. Craven, U. S. N	350
Cape Romain..	...do	1-10, 000	1874	W. H. Dennis	1238 a b
Cape Romain to Charleston	...do	1-40, 000	1857	J. N. Maffitt, U. S. N......	626
Bulls' Bay	...do	1-20, 000	1857	J. P. Bankhead, U. S. N...	683
Charleston Harbor and Bar	.. do	1-10, 000	1851	J. N. Maffitt, U. S. N......	254
Charleston Harbor entrance...........................	...do	1-5, 000	1852	.....do	536
Maffitt's Channel and North Channel, Charleston Harbor	....do	1-5, 000	1857	.....do	623
North Channel and Maffitt's Channel, Charleston Harbor	...do	....	1855	.....do	476
Maffitt's Channel, Charleston Harbor	...do	1-10, 000	1854	......do	411
Maffitt's Channel (resurvey)	...do	1-5, 000	1856	.....do	532
Main ship-bar, Charleston Harbor	...do	1-10, 000	1857	......do	625
Charleston Harbor Bar (resurvey)	...do	1-20, 000	1863-'4	W. S. Edwards, F. P. Webber	852
Main channel over Charleston Bar....................	...do	1-20, 000	1869	R. E. Halter ,............	981
Charleston Bar..	...do	1-20, 000	1865	C. O. Boutelle	874
Charleston Harbor....................................	.. do	1-10, 000	1865	.....do	881
Maffitt's Channel, Charleston Harbor (resurvey).......	.. do	1-10, 000	1860	J. P. Bankhead, U. S. N...	718
Light-House Inlet, Charleston Harbor	...do	1-10, 000	1863-'4	C. O. Boutelle............	853
Stono Inlet and River, and part of Kiawah and Folly Rivers.	....do	1-20, 000	1862	......do	803
Off shore, between Charleston and Savannah entrance	...do	1-200, 000	1857	J. N. Maffitt, U. S. N......	622
From Charleston to Savannah.........................	...do	1-10, 000	1853-'7	.....do	649
North Edisto Harbor and Bar.........................	...do	1-20, 000	1851	......do	272
North Edisto Bar	...do	1-20, 000	1856	.....do	534
Saint Helena Sound and Bar, South Edisto River	...do	1-15, 000	1856-'7	.....do	620
Passages between Port Royal Bay and Saint Helena Sound, sheet No. 1.	...do	1-10, 000	1863	W. S. Edwards............	832
Passages between Port Royal Bay and Saint Helena Sound, sheet No. 2.	.. do	1-10, 000	1863	.....do	833
Bull and Combahee Rivers	...do	1-10, 000	1871	Charles Hosmer..........	1084
Combahee and Ashepoo Rivers and estuaries	...do	1-10, 000	1873	.....do	1206
Parrott Creek, from Coosaw to Morgan River	....do	1-10, 000	1860	J. P. Bankhead, U. S. N...	744
Coosaw River, from Combahee River to Brickyard Creek.	....do	1-10, 000	1860	.....do	742
Brickyard Creek, from Coosaw River to Beaufort.....	...do	1-10, 000	1860	.....do	743
Inland passages from Coosaw River to Beaufort River	...do	1-20, 000	1872	Charles Hosmer..........	1155 a
Coosaw River to Broad River via Whale Branch......	...do	1-10, 000	1873	.....do	1155 b
Port Royal entrance	...do	1-20, 000	1859	C. M. Fauntleroy, U. S. N	677
Beaufort River (reconnaissance)	...do	1-10, 000	1855	J. N. Maffitt, U. S. N......	633
Port Royal entrance and Beaufort Harbor	...do	1-20, 000	1855-'6	.....do	535
Port Royal entrance	.. do	1-20, 000	1863	C. O. Boutelle	830

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Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Port Royal Bay and Broad River	South Carolina	1-20, 000	1862-'3	C. O. Boutelle	831
Broad River	...do	1-10, 000	1865	R. E. Halter	869
Broad River and tributaries	...do	1-10, 000	1865	.....do	868
Beaufort River, from its mouth to Little Marsh Island	...do	1-10, 000	1862	C. O. Boutelle	802
Beaufort River, from Marsh Island to Beaufort	...do	1-10, 000	1862	.....do	834
Jericho, Chowan, and Ballast Creeks, tributaries of Beaufort River.	...do	1-10, 000	1868	Charles Hosmer	962
Chichessee and Colleton Rivers	...do	1-10, 000	1859	C. M. Fauntleroy, U. S. N.	679
Calibogue Sound and part of Broad Creek	...do	1-10, 000	1862	C. O. Boutelle	804
Skull Creek	...do	1-10, 000	1861-'2	.....do	805
Savannah River Bar	South Carolina and Georgia.	1-20, 000	1854	J. N. Maffitt, U. S. N	439
Savannah River Bar (reconnaissance)	...do	1-20, 000	1851	.....do	269
Savannah River entrance	...do	1-10, 000	1852	.....do	317
Savannah River	...do	1-10, 000	1850	.....do	267
Savannah River, Hutchinson and Elba Islands	...do	1-5, 000	1852	.....do	318
Savannah River, Front and Back Rivers	...do	1-10, 000	1851	.....do	266
Savannah River, part of Hutchinson and Argyle Islands	...do	1-5, 000	1852	.....do	319
Savannah River, Argyle, Onslow, and Isla Islands	...do	1-5, 000	1852	.....do	320
Savannah River, opposite Fort Pulaski, showing the position of obstructions.	...do	1-10, 000	1862	C. O. Boutelle	807
Off-shore soundings, between Winyah Bay and Amelia Island.	South Carolina, Georgia, and Florida.	1-300, 000	1858	T. B. Huger, U. S. N.	653
Off-shore soundings between Winyah Bay and Amelia Island (replotted).	...do	1-300, 000	1858	.....do	717
Off-shore soundings, between Charleston Harbor and Saint Andrew's Sound.	South Carolina and Georgia.	1-300, 000	1860	J. P. Bankhead, U. S. N	728
Off-shore soundings, from Port Royal entrance, to Wassaw Sound, Geskin and Joiner's Banks.	...do	1-40, 000	1866	C. O. Boutelle	966
Savannah River entrance	Georgia	1-20, 000	1866	.....do	944
Lazaretto Creek and part of Tybee Roads	...do	1-10, 000	1863	W. S. Edwards	842
Savannah River, from Tybee light to Elba Island	...do	1-10, 000	1866	C. O. Boutelle	945
Savannah River, from Elba Island to Fig Island	...do	1-10, 000	1865-'6	.....do	946
Savannah River, city front	...do	1-5, 000	1865-'6	.....do	947
Savannah River (with topography), 2 sheets	...do	1-2, 400	1874	Charles Hosmer	1222 a b
Savannah River (with topography), 2 sheets	...do	1-2, 400	1874	.....do	1223 a b
Wilmington River and estuaries	...do	1-20, 000	1865	C. Fendall	866
Romerly Marshes	...do	1-5, 000	1856	J. N. Maffitt, U. S. N.	617
Entrance to Wassaw Sound	...do	1-20, 000	1864-'6	C. O Boutelle	904 a
Confluence of the Tybee and Wilmington Rivers	...do	....	1863	W. S. Edwards	904 b
Ogeechee, Vernon, and Burnside Rivers	...do	1-20, 000	1865	C. Fendall	867
Ossabaw Sound and Vernon and Ogeechee Rivers	...do	1-20, 000	1860	C. M. Fauntleroy, U. S. N.	733
Saint Catharine's Sound and estuaries	...do	1-20, 000	1867	Charles Junken	916
Saint Catharine's entrance	...do	1-20, 000	1867	.....do	928
Sapelo Sound	...do	1-10, 000	1858	J. H. Moore, U. S. N	659
Sapelo Sound and adjacent waters	...do	1-10, 000	1858	.....do	660
Sapelo Bar and approaches	...do	1-20, 000	1859	C. M. Fauntleroy, U. S. N.	691
Inland passages between Sapelo and Doboy Sounds	...do	1-10, 000	1868	Charles Junken	959
Doboy Bar and Sound (reconnaissance)	...do	1-20, 000	1854	T. A. Craven, U. S. N.	461
Doboy Inlet and approaches	...do	1-20, 000	1868	Charles Junken	957
Doboy Sound, with Darien and North Rivers and adjacent creeks.	...do	1-10, 000	1868	.....do	964
Doboy and Saint Simon's Sounds	...do	1-20, 000	1872	F. P. Webber	1146
Coast from Altamaha Sound to Saint Simon's Sound	...do	1-20, 000	1860	J. P. Bankhead, U. S. N.	810
Saint Simon's entrance	...do	1-10, 000	1856-'7	S. D. Trenchard, U. S. N.	590
Saint Simon's Bar and Brunswick Harbor	...do	1-10, 000	1856	.....do	537
Saint Simon's Bar and Brunswick Harbor	...do	1-10, 000	1856	.....do	548
Brunswick Harbor	...do	1-10, 000	1856	.....do	575
Brunswick Harbor and Turtle River	...do	1-10, 000	1857	.....do	587
Saint Simon's to Saint Andrew's Sound	...do	1-20, 000	1869-'72	R. E. Halter and F. P. Webber.	1133
Saint Andrew's and Jekyl Sounds	...do	1-20, 000	1870	R. E. Halter	1090

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Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Coast from Saint Andrew's Bar to Saint Mary's Bar	Georgia	1-20,000	1870	Charles Junken	1062
Florida Passage, from Saint Andrew's Sound to Cumberland Island.	do	1-20,000	1870	do	1063
Saint Mary's Bar and Fernandina Harbor	Georgia and Florida.	1-10,000	1855-'6-'7	S. D. Trenchard, U. S. N.	591
Saint Mary's Bar (resurvey)	do	1-10,000	1857	do	571
Saint Mary's Bar and Fernandina Harbor	do	1-20,000	1855	R. Wainwright, U. S. N.	479
Saint Mary's entrance and Fernandina Harbor	do	1-10,000	1855-'6-'7	S. D. Trenchard, U. S. N.	579
Saint Mary's River	do	1-10,000	1856	do	592
Part of Saint Mary's River up to Saint Mary's	do		1856	do	550
Off-shore soundings from Fernandina to Cape Florida	do	1-400,000	1860	A. Murray, U. S. N.	770
Main ship-channel over Saint Mary's River Bar	Florida	1-20,000	1869	R. E. Halter	980
Saint Mary's River Bar (2 sheets)	do	1-10,000	1874	F. D. Granger	1218 *a b*
Saint Mary's River and estuaries	do	1-10,000	1871	F. P. Webber	1112
Nassau Sound and estuaries	do	1-10,000	1871	do	1113 *a*
Part of Nassau Sound	do	1-10,000	1871	do	1113 *b*
Coast from Saint Mary's to Saint John's Bar	do	1-20,000	1871	do	1110
Fernandina to Saint John's River	do	1-10,000	1871	do	1111
Nassau Sound to Saint John's River	do	1-10,000	1872	do	1147
Saint John's River entrance and Fort George Inlet	do	1-10,000	1853	T. A. Craven, U. S. N.	351
Saint John's Bar and vicinity (current-chart)	do		1855	R. Wainwright, U. S. N., S. D. Trenchard, U. S. N.	511
Saint John's River Bar (resurvey)	do	1-10,000	1857	S. D. Trenchard, U. S. N.	586
Saint John's River, Mayport Mills to Brown's Creek	do	1-10,000	1855	R. Wainwright, U. S. N.	481
Saint John's River, Brown's Creek to Six Mile Creek	do	1-10,000	1855	do	482
Saint John's River, Jacksonville and vicinity	do	1-10,000	1855	do	484
Coast between Saint John's and Augustine Bars	do	1-20,000	1874	F. D. Granger	1224
Saint Augustine and vicinity	do	1-10,000	1870	H. Anderson	1036
Saint Augustine Harbor approaches	do	1-10,000	1860	A. Murray, U. S. N.	712
Saint Augustine Harbor, and North and Matanzas Rivers.	do	1-10,000	1860	do	711
North and Guano Rivers	do	1-10,000	1870	H. Anderson	1046
Matanzas River	do	1-10,000	1870	do	1047
Matanzas River	do	1-5,000	1872	A. M. Harrison	1148 *a*
Matanzas River and Inlet	do	1-5,000	1872	do	1148 *b*
Part of Halifax River (3 sheets)	do	1-5,000	1874	do	1232 *a b c*
Part of Halifax River (2 sheets)	do	1-5,000	1874	do	1233 *a b*
Halifax River and tributaries (2 sheets)	do	1-5,000	1874	do	1234 *a b*
Mosquito Inlet (reconnaissance)	do	1-20,000	1851	John Rodgers, U. S. N.	260
Cape Canaveral Shoals (reconnaissance)	do	1-20,000	1850	do	234
Key Biscayne and vicinity	do	1-20,000	1852	do	407
Key Biscayne and Card Sound	do	1-20,000	1854	T. A. Craven, U. S. N.	444
Florida Reef, Triumph Reef, and Old Rhodes Bank	do	1-20,000	1853	do	369
Pacific Reef to Carysfort Reef	do	1-20,000	1854	do	443
Carysfort Reef to Grecian Shoal	do	1-20,000	1855	do	568
Florida Reefs, Grecian Shoal to French Reef	do	1-20,000	1856	do	553
Florida Reefs, between Alligator and French Reefs	do	1-40,000	1863	E. Cordell	777
Florida Reefs, abreast of Upper and Lower Matecumbe Keys.	do	1-20,000	1862	G. Davidson	774
Florida Reefs, from Coffin's Patches to Tennessee Reef	do	1-20,000	1860	J. Wilkinson, U. S. N.	773
Coffin's Patches, Florida Reefs	do	1-20,000	1854	T. A. Craven, U. S. N.	417
Florida Reefs, from Coffin's Patches to Boot Key	do	1-20,000	1859	do	714
Florida Reefs, from Bahia Honda to Key Vaccas	do	1-20,000	1858	W. G. Temple, U. S. N.	663
Florida Reefs, from American Shoal to Sombrero	do	1-20,000	1857	T. A. Craven, U. S. N.	669
Florida Reefs, from East Sambo to Loggerhead Key	do	1-20,000	1856	do	650
Additional soundings off Boca Chica	do	1-20,000	1863	E. Cordell	779
Key West Harbor and vicinity	do	1-20,000	1851	John Rodgers, U. S. N.	281
Approaches to Key West from the northwest	do	1-80,000	1872	Robert Platt, U. S. N.	1131
Key West Harbor	do	1-5,000	1850-'1-'2	John Rodgers, U. S. N.	338
Marquesas Keys and vicinity of Boca Grande	do	1-20,000	1851-'2	do	282
Boca Grande, Marquesas Keys and vicinity	do	1-20,000	1852	do	359
Rebecca Shoals, (reconnaissance)	do	1-10,000 1-30,000	1852	do	313

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Tortugas Harbor, part of	Florida	1-5,000	1873	J. A. Howell, U. S. N	1199
Off-shore soundings from Sambrero to Sand Keys	do	1-160,000	1868	R. Platt, U. S. N	1066
Off-shore soundings, Straits of Florida westward	do	1-400,000	1869	do	1090
Off-shore soundings, Straits of Florida eastward	do	1-400,000	1869	do	1091
Off-shore soundings from Key West to Charlotte Harbor	do	1-400,000	1867	do	911
Off-shore soundings from Sand Keys to Marquesas Keys	do	1-40,000	1867	do	912
Off-shore soundings from Marquesas Keys to Rebecca Shoals.	do	1-40,000	1870	do	1052
Off-shore soundings, approaches to Dry Tortugas Keys	do	1-40,000	1867-'8	do	955
Florida Reefs, from Marquesas to Dry Tortugas Keys	do	1-80,000	1867-'8	do	954
Florida Reefs, western end Marquesas to Dry Tortugas Keys.	do	1-80,000	1871	do	1076
El Moro to Playa de Marianao, north coast of Cuba	Cuba	1-10,000	1867	W. S. Edwards	900
Yucatan Channel, from Cape San Antonio, Cuba, to Catoche, Yucatan.	Mexico	1-200,000	1872	R. Platt, U. S. N	1137
San Carlos Bay and Caloosa entrance	Florida	1-20,000	1866-'7	W. S. Edwards	917
Pine Island Sound, part of, and approaches to the Caloosahatchee.	do	1-20,000	1866	C. T. Iardella	903
Charlotte Harbor, main entrance	do	1-40,000	1863	E. Cordell	797
Tampa Bay (reconnaissance)	do	1-60,000	1855	O. H. Berryman, U. S. N	478
Tampa Bay (2 sheets)	do	1-20,000	1874	A. Braid	1235 *a b*
Boca Ceigo Bay, from John's Pass to Tampa Bay	do	1-20,000	1873	H. G. Ogden	1178 *a*
Boca Ceigo Bay, from Indian Pass to John's Pass	do	1-20,000	1873	do	1178 *b*
Clearwater Harbor	do	1-20,000	1873	do	1174
Waccasassa Bay	do	1-20,000	1857	J. K. Duer, U. S. N	581
Waccasassa Bay	do	1-20,000	1856	do	531
Cedar Keys (reconnaissance of Channel No. 4)	do	1-10,000	1852	F. H. Gerdes	304
Cedar Keys	do	1-20,000	1854	O. H. Berryman, U. S. N	424
Cedar Keys	do	1-20,000	1855	do	513
Cedar Keys	do	1-20,000	1855	do	512
Cedar Keys (resurvey)	do	1-10,000	1860	J. J. Guthrie, U. S. N	713
Cedar Keys, Northwest Channel, and Sea Horse Channel Bars.	do	1-10,000	1860	do	716
Cedar Keys, resurvey of Main and North Keys	do	1-10,000	1858-'9	T. B. Huger, U. S. N	668
Cedar Keys, main channel	do	1-10,000	1871	F. P. Webber	1080
Ocilla River	do	1-10,000	1855	O. H. Berryman, U. S. N	517
Saint Mark's River	do	1-10,000	1856	do	541
Saint Mark's River Bar	do	1-20,000	1856	do	540
Saint Mark's River Bar and Channel (reconnaissance)	do	1-20,000	1852	F. H. Gerdes	305
Saint George's Sound, Saint Joseph's and Saint Mark's (reconnaissance).	do		1852	do	307
Saint George's Sound, new channel	do	1-20,000	1858-'9	J. K. Duer, U. S. N	688
Saint George's Sound, eastern part	do	1-20,000	1860	T. S. Phelps, U. S. N	734
Saint George's Sound, east pass	do	1-20,000	1858	J. K. Duer, U. S. N	655
Saint George's Sound, west pass	do	1-20,000	1858	do	654
Off eastern part of Saint George's Sound, from East Pass to Southwest Cape.	do	1-20,000	1872	H. Anderson	1156
Saint George's Sound	do	1-20,000	1871	do	1092
Saint George's Sound	do	1-40,000	1873	do	1184
Appalachicola River, mouth of	do	1-20,000	1859	J. K. Duer, U. S. N	687
Appalachicola Bay	do	1-20,000	1860	T. S. Phelps, U. S. N	747
Saint Vincent Sound	do	1-20,000	1874	H. Anderson	1241
Saint Andrew's Bay	do	1-20,000	1856	O. H. Berryman, U. S. N	518
Saint Andrew's Bay	do	1-20,000	1855	do	514
Choctawhatchee Bay	do	1-20,000	1872	H. G. Ogden	1141
Santa Rosa Sound, The Narrows, and west end of Choctawhatchee Bay.	do	1-20,000	1871	do	1107
Santa Rosa Sound, from Deer Point to Long Pritchard Point.	do	1-20,000	1871	do	1108
Santa Maria de Galvaes Bay	do	1-20,000	1860	T. S. Phelps, U. S. N	731
Escambia Bay	do	1-20,000	1860	do	732
Pensacola Harbor, shoal spot off navy-yard	do	1-10,000	1860	T. A. Craven, U. S. N	719
Pensacola Bar and Bay entrance	do	1-20,000	1856	J. K. Duer, U. S. N	585

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
West coast of Florida	Florida	1-600,000	1872	J. A. Howell, U. S. N	1138
Key West to Delta	...do	1-120,000	1857-'8	B. F. Sands, U. S. N	599
Gulf of Mexico, soundings and temperatures			1856	.... do	528
Gulf of Mexico, deep-sea temperatures		1-1,200,000	1854-'5	.....do	483
Gulf of Mexico, deep-sea soundings and temperature			1855	O. H. Berryman, U. S. N	468
Soundings from Mobile Bay to Mississippi Delta	Alabama	1-600,000	1854	B. F. Sands, U. S. N	420
Mobile Bay, eastward from Fort Morgan	...do	1-20,000	1851	.....do	262
Pelican Channel (resurvey)	...do	1-20,000	1853	.....do	361
Pelican Channel (resurvey)	...do	1-20,000	1855	.....do	467
Mobile Bay, north of Dauphine Island	...do	1-20,000	1847	C. P. Patterson, U. S. N	191
Mobile Bay, approaches and entrance	...do	1-20,000	1847-'8	.....do	192
Mobile Bay, lower part	...do	1-20,000	1848	.....do	193
Mobile Bay, lower part	...do	1-20,000	1849	.....do	215
Bonsecour Bay	...do	1-20,000	1851	James Alden, U. S. N	263
Mobile Bay, middle and upper part	...do	1-20,000	1850	.....do	227
Mobile Bay, upper part and Dog River Bar	.. do	1-10,000	1849	C. P. Patterson, U. S. N	214
Mobile Bay, Delta and Mobile City	...do	1-10,000	1850	James Alden, U. S. N	228
Mobile Bay, Upper Delta	...do	1-10,000	1850	.....do	229
Tensaw, Spanish, and Mobile Rivers, and Dog River Bar (resurvey).	...do	1-10,000	1860	J. Wilkinson, U. S. N	737
From Murder Point to Grand Bay, Mississippi Sound	Mississippi	1-20,000	1852	B. F. Sands, U. S. N	329
Off shore, westward from Fort Morgan, Mississippi Sound.	...do	1-20,000	1851	.....do	261
Horn Island Passage to Pascagoula, Mississippi Sound	...do	1-20,000	1852-'3	.....do	328
From Pascagoula River to east end of Horn Island	...do	1-20,000	1853	.....do	365
Horn Island Channel, Mississippi Sound	...do	1-20,000	1846	C. P. Patterson, U. S. N	190
Horn Island Pass	.. do	1-20,000	1852	B. F. Sands, U. S. N	327
Horn Island Pass (resurvey)	...do	1-20,000	1853	.....do	362
Southward of Horn and Ship Islands	...do	1-20,000	1854	.....do	430
Between Horn Island and Ship Island	...do	1-20,000	1855	.....do	489
Biloxi Bay	...do	1-20,000	1855	.....do	485
Mississippi Sound, from Cat Island to Mississippi City	....do	1-20,000	1855	.....do	488
Mississippi Sound, Cat and Ship Islands	....do	1-20,000	1848	C. P. Patterson, U. S. N	194
Saint Louis Bay and part of Mississippi Sound	....do	1-20,000	1856	B. F. Sands, U. S. N	546
Pass Christian	... do	1-10,000	1851	.....do	256
Pass Christian and part of Mississippi Sound (resurvey)	... do	1-20,000	1857	.....do	589
Part of Chandeleur Sound and Nassau Roads	Mississippi and Louisiana.		1857	.....do	598
Grand Island Pass and Pearl River entrance	....do	1-20,000	1856	.....do	545
Grand Gulf	Mississippi	1-5,000	1864	F. H. Gerdes	846
Ship Island Shoal	Louisiana	1-20,000	1853	B. F. Sands, U. S. N	360
Nassau Roads, north of Chandeleur Island	....do	1-20,000	1852	......do	363
Chandeleur Sound	....do	1-40,000	1873	F. D. Granger	1171
Lake Borgne	....do	1-40,000	1870	F. P. Webber	1055 a
Eastern part of Lake Pontchartrain	....do	1-40,000	1870	......do	1055 b
The Rigolets	....do	1-20,000	1870	......do	1054
The Rigolets	....do	1-10,000	1859	W. S. Gilbert	671
Lake Pontchartrain	....do	1-40,000	1871	J. S. Bradford	1115
Isle au Breton Bay	....do	1-40,000	1869	F. P. Webber	999
Isle au Breton Sound, southeast part	....do	1-40,000	1869	.....do	1000
Delta Mississippi River (reconnaissance)	....do	1-20,000	1851	B. F. Sands, U. S. N	255
Approaches to Mississippi River	....do	1-40,000	1871	J. S. Bradford	1116
Approaches to Mississippi River	....do	1-40,000	1872	F. D. Granger	1152
Pass à Loutre, Mississippi Delta	....do	1-20,000	1860	J. J. Guthrie, U. S. N	715
Pass à Loutre and Southeast Pass	... do	1-20,000	1867	F. H. Gerdes	989
Pass à Loutre and bar	....do	1-10,000	1867	......do	927
Northeast and Southeast Passes	....do	1-10,000	1867	......do	926
West, East, and Garden Island Bays	....do	1-40,000	1868	F. P. Webber	991
South Pass	....do	1-20,000	1867	F. H. Gerdes	990
South Pass Bar	....do	1-10,000	1867	.....do	925
Southwest Pass	....do	1-20,000	1867	......do	923
Southwest Pass and Bar	....do	1-10,000	1867	...... do	924
Southwest and South Passes	... do	1-20,000	1852	B. F. Sands, U. S. N	330

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Mississippi River, part of	Louisiana	1-10,000	1866	F. H. Gerdes	922
Mississippi River, from North Base to Grand Prairie	.. do	1-20,000	1872	F. D. Granger	1153
Mississippi River, from Grand Prairie to Bohemia	.. do	1-20,000	1871	C. H. Boyd	1093
Mississippi River, from Bohemia to Poverty Point	.. do	1-20,000	1872	......do	1154
Mississippi River, from Poverty Point to Scarsdale	.. do	1-20,000	1873	......do	1192
Barataria Harbor and Bar (reconnaissance)	.. do	1-10,000	1853	F. H. Gerdes	441
From Southwest Pass to Atchafalaya Bay (reconnaissance).	.. do	1-20,000	1853	......do	442
Atchafalaya Bay	.. do	1-20,000	1858	B. F. Sands, U. S. N	658
Atchafalaya approaches	.. do	1-20,000	1859	T. B. Huger, U. S. N	680
Atchafalaya Bay	.. do	1-20,000	1859	......do	681
Côte Blanche Bay, eastern part	...do	1-20,000	1859	..... do	682
Vermillion Bay entrance (reconnaissance)	.. do	1-20,000	1855	B. F. Sands, U. S. N	486
Calcasieu River (reconnaissance)	...do	1-20,000	1855	..... do	487
Trinity Shoal	.. do	1-40,000	1872	F. D. Granger	1139 *a*
Trinity and Tiger Shoals	.. do	1-80,000	1872	......do	1139 *b*
Off shore from Timballier Bay to Galveston Bar	Louisiana and Texas.	1-635,000	1858	J. K. Duer, U. S. N	657
Galveston Bay, upper part, Turtle Bay to Smith's Point	Texas	1-20,000	1855	E. J. De Haven, U. S. N	470
Galveston Bay, from Smith's Point to Edward's Point	.. do	1-20,000	1852	T. A. Craven, U. S. N	324
Galveston Bay, from Bolivar Point to Hanna's Island	...do	1-20,000	1852	......do	323
Galveston Bay, western part	.. do	1-20,000	1853-'4	H. S. Stellwagen, U. S. N., E. J. De Haven, U. S. N.	414
East Galveston Bay	...do	1-20,000	1854	E. J. De Haven, U. S. N	425
Off Galveston Bar and westward	...do	1-20,000	1855	......do	471
Galveston Bar, outside and southward	...do	1-20,000	1851	T. A. Craven, U. S. N	265
Galveston Harbor	...do	1-20,000	1851	......do	264
Galveston Harbor	.. do	1-20,000	1850	A. S. Baldwin, U. S. N	247
Galveston entrance and bar	...do	1-10,000	1867	F. F. Nes	906
Galveston Bay, resurvey	...do	1-10,000	1867	......do	918
Galveston Bay, resurvey	...do	1-10,000	1867	C. H. Boyd	919
Galveston Harbor, comparative chart showing changes from 1851 to 1867.	.. do	1-10,000	1867	......do	919 *bis.*
Galveston Bay, western entrance	...do	1-20,000	1867	F. F. Nes	931
West Galveston Bay	... do	1-20,000	1867	......do	932
Westward of Galveston Bar and Galveston Island	... do	1-20,000	1855	E. J. De Haven, U. S. N	472
Westward from Galveston Island	... do	1-20,000	1855	..... do	473
San Luis Pass	... do	1-10,000	1853	H. S. Stellwagen, U. S. N	389
Brazos River Bar	...do	1-10,000	1858	J. K. Duer, U. S. N	656
From Velasco westward, along the coast	... do	1-20,000	1855	E. J. De Haven, U. S. N	474
Gulf Coast, from Quintana westward	...do	1-20,000	1856	......do	539
Matagorda Bay, from Matagorda to Palacios	...do	1-20,000	1859	J. K. Duer, U. S. N	689
Matagorda Bay, northeast part	... do	1-10,000	1871-'2	L. B. Wright	1161
Matagorda Bay, northwest part	...do	1-20,000	1860	W. Ronckendorff, U. S. N	727
Trespalacios and Turtle Bays	...do	1-20,000	1871	F. D. Granger	1094
Carancahua Bay	...do	1-20,000	1871	..... do	1095
Lavaca Bay and vicinity	...do	1-20,000	1871	...... do	1098
Matagorda Bay entrance, Paso del Cavallo	...do	1-20,000	1858	A. Balbach	635
Pass Cavallo	...do	1-20,000	1871	F. D. Granger	1097
Pass Cavallo Bar	... do	1-10,000	1874	L. B. Wright	1231
Matagorda Bay, part of	...do	1-20,000	1866-'71	F. P. Webber and F. D. Granger.	1031
Espiritu Santo Bay and part of San Antonio Bay	...do	1-20,000	1871-'2	F. D. Granger and L. B. Wright.	1096
Aransas Pass	... do	1-10,000	1854	H. S. Stellwagen, U. S. N	386
Aransas Pass	...do	1-10,000	1868	F. F. Nes	996
Aransas Bay	... do	1-20,000	1869	H. Anderson	995
Corpus Christi Pass	...do	1-10,000	1869	......do	994
Corpus Christi Bay	...do	1-20,000	1868	F. F. Nes	958
Entrance to Brazos Santiago and Laguna Madre	...do	1-20,000	1867	C. H. Boyd	909
Rio Grande River and Bar (reconnaissance)	... do	1-10,000	1853	John Wilkinson, U. S. N	377
Soundings in the Lower Ohio River, between Cairo and Mound City.	Interior States, Illinois.	1-10,000	1864	F. H. Gerdes and C. Fendall.	851

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
San Diego, California, to Panama (3 sheets and 5 plans)	Mexico	1-400,000	1873	P. C. Johnson, U. S. N	1202abc
Magdalena Bay, from the Narrows to Cayuco Cove	Lower California	1-20,000	1871	G. Bradford	1123
Magdalena Bay, Man-o'-war Cove to the Narrows	do	1-40,000	1871	do	1124
San Diego Bay and vicinity	California	1-10,000	1856	James Alden, U. S. N	564
San Diego Bay	do	1-10,000	1856	do	565
San Diego Bay	do	1-10,000	1856	do	566
San Diego Bay	do	1-10,000	1856	do	567
San Diego Harbor (reconnaissance)	do	1-10,000	1851	R. D. Cutts	268
Coast, from San Diego to Point Conception (reconnaissance).	do		1851	James Alden, U. S. N	289
Cortez Bank, shoal southwest of San Diego	do	1-5,000	1853	T. H. Stevens, U. S. N	355
Cortez Bank, shoal southwest of San Diego	do	1-40,000	1856	James Alden, U. S. N	542
San Clemente Anchorage, southeast end of island	do	1-10,000	1856	do	543
San Clemente Anchorage, northwest end of island	do	1-10,000	1852	do	312
Catalina Island Anchorage, northeast side	do	1-5,000	1852	do	308
Catalina Harbor and Anchorage, northeast side	do	1-5,000	1851	do	291
Catalina Harbor and Isthmus Cove	do	1-10,000	1873	P. C. Johnson, U. S. N	1210
San Pedro and vicinity of Los Angeles	do	1-10,000	1852	James Alden, U. S. N	310
San Pedro Anchorage	do	1-10,000	1854	T. H. Stevens, U. S. N	437
San Pedro Harbor and approaches	do	1-10,000	1859	James Alden, U. S. N	706 a
San Pedro Harbor, Wilmington Breakwater	do	1-10,000	1873	A. W. Chase	706 b
Off-shore soundings, Point Pedro, Santa Cruz	do	1-100,000	1865	E. Cordell	871
Shoo-Fly Landing	do	1-10,000	1873	P. C. Johnson, U. S. N	1121
Anacapa and eastern end of Santa Cruz Island	do	1-10,000	1855	James Alden, U. S. N	501
Prisoner's Harbor, Santa Cruz Island	do	1-10,000	1852	do	303
Santa Cruz Channel	do	1-20,000	1873-'4	P. C. Johnson, U. S. N	1221 a
Santa Cruz Island, north side, from West Point to Punta Diablo.	do	1-20,000	1874	H. C. Taylor, U. S. N	1221 b
Point Hueneme and vicinity, Santa Barbara Channel	do	1-10,000	1856	James Alden, U. S. N	554
Harbor of Buenaventura	do	1-10,000	1870	W. E. Greenwell	1081
San Buenaventura and vicinity	do	1-10,000	1855	James Alden, U. S. N	503
Santa Barbara and vicinity	do	1-10,000	1852	do	311
Santa Barbara	do	1-10,000	1854	T. H. Stevens, U. S. N	436
Santa Barbara Channel, inshore soundings, No. 1	do	1-10,000	1869	E. Cordell, G. Farquhar	1038
Santa Barbara Channel, inshore soundings, No. 2	do	1-10,000	1869	do	1039
Santa Barbara Channel, inshore soundings, No. 3	do	1-10,000	1869	do	1040
Santa Barbara Channel, inshore soundings, No. 4	do	1-10,000	1869	do	1041
Santa Barbara Channel, inshore soundings, No. 5	do	1-10,000	1869	do	1042
Santa Barbara Channel, inshore soundings, No. 6	do	1-10,000	1869	do	1043
Santa Barbara Channel, inshore soundings, No. 7	do	1-10,000	1869	do	1044
Santa Barbara Channel, off-shore soundings	do	1-100,000	1869	do	1045
Santa Barbara Channel, entrance Coxo Anchorage	do	1-10,000	1869	do	1037
Cuyler's Harbor, island of San Miguel	do	1-10,000	1852	James Alden, U. S. N	309
Point Concepcion and vicinity of Coxo	do	1-20,000	1852	do	295
Coast from Point Concepcion to San Francisco entrance	do	1-375,000	1851	do	290
Roadstead under Point Sal	do	1-5,000	1867	E. Cordell	921
San Luis Obispo and vicinity	do	1-10,000	1852	James Alden, U. S. N	302
San Simeon Bay and vicinity	do	1-10,000	1852	do	301
Coast from Point Pinos to Cape Mendocino (reconnaissance).	do	1-1,000,000	1851	W. P. McArthur, U. S. N	241
Sanquel Cove, Monterey Bay	do	1-10,000	1855	James Alden, U. S. N	504
Santa Cruz Harbor, Monterey Bay (reconnaissance)	do	1-10,000	1852	do	300
Santa Cruz Harbor, Monterey Bay	do	1-10,000	1853	do	379
Monterey Bay	do	1-20,000	1851	do	296
Monterey Bay	do	1-40,000	1856	do	558
Monterey Bay	do	1-10,000	1856	do	559
Monterey Bay	do	1-10,000	1856	do	560
Monterey Bay	do	1-10,000	1856	do	561
William's Landing and vicinity, Monterey Bay	do	1-10,000	1855	do	505
William's Landing and westward, Monterey Bay	do	1-10,000	1855	do	506
Point Año Nuevo and southward	do	1-10,000	1853	do	380
Point Año Nuevo and northward	do	1-10,000	1856	do	555
Coast northward of Pigeon Point	do	1-10,000	1856	do	556

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Part of coast south of Half-Moon Bay	California	1-10,000	1863	A. F. Rodgers	825
Half-Moon Bay	do	1-10,000	1863	do	821
Point Pedro to Half-Moon Bay	do	1-10,000	1863	do	835
San Francisco, entrance and westward	do	1-80,000	1857	James Alden, U. S. N	562
Coast from San Francisco northward to Crescent City	do		1854	do	401
San Francisco Bay, approaches and entrance	do	1-100,000	1858-'9-'60	do	721
San Francisco entrance, and bar	do	1-20,000	1855	do	456
San Francisco Bar and part of entrance	do	1-10,000	1873	G. Bradford	1201
San Francisco Bay	do	1-20,000	1873	do	1214
San Francisco Bay, from Point Bonita to Angel Island	do	1-10,000	1855	James Alden, U. S. N	462
San Francisco Bay, Angel Island to Point Avisadera	do	1-20,000	1855	do	464
San Francisco Bay, Point Avisadera to Point Bueno	do	1-10,000	1854	do	421
San Francisco Bay, Point Avisadera to Coyote Hill Creek	do	1-20,000	1857-'8	J. Alden, R. M. Cuyler, U. S. N	628
San Francisco Bay, Steinbergen and Redwood City Creeks.	do	1-10,000	1858	R. M. Cuyler, U. S. N	637
San Francisco Bay, from Ravenwood to Coyote Creek	do	1-10,000	1857-'8	do	636
San Francisco Bay, Coyote Hill and Union City Creeks	do	1-10,000	1858	do	638
San Francisco Bay, San Antonio Creek	do	1-10,000	1857	James Alden, U. S. N	573
San Francisco Harbor, vicinity of the city	do	1-10,000	1853	do	347
San Francisco Bay	do	1-10,000	1857-'8	R. M. Cuyler, U. S. N	629
San Francisco city front (resurvey)	do	1-10,000	1857	do	604
Richmond Bay and Raccoon Strait, San Francisco Bay	do	1-10,000	1855	James Alden, U. S. N	463
San Francisco Bay, from Angel Island to Richmond Point.	do	1-10,000	1855	do	465
San Francisco Bay, from Point San Pablo to Point San Quentin.	do	1-10,000	1855	do	466
Petaluma Creek, from entrance to Lakeville	do	1-10,000	1860	do	724
Petaluma Creek, from Lakeville to Petaluma City	do	1-10,000	1860	do	725
San Pablo Bay	do	1-20,000	1856	do	524
Channel off Point Wilson, San Pablo Bay	do	1-20,000	1863	A. F. Rodgers	781
Resurvey of channel off Point Wilson, San Pablo Bay	do	1-20,000	1862	B. F. Sands, U. S. N	758
Napa Creek	do	1-10,000	1860	James Alden, U. S. N	723
Resurvey of approaches to Mare Island navy-yard	do	1-10,000	1862	B. F. Sands, U. S. N	759
Mare Island Strait (reconnaissance)	do	1-5,000	1849	W. P. McArthur, U. S. N	288
Mare Island Strait (reconnaissance)	do	1-5,000	1850	do	296
Mare Island Strait	do	1-10,000	1856	James Alden, U. S. N	544
Mare Island Strait (resurvey)	do	1-5,000	1864	Rodgers, Lawson, Edwards	838
Carquines Strait	do	1-10,000	1857	James Alden, U. S. N	563
Resurvey of part of Carquines Strait	do	1-10,000	1862	B. F. Sands, U. S. N	760
Part of Carquines Straits	do	1-20,000	1863	A. F. Rodgers	782
Part of Carquines Straits	do	1-10,000	1866	E. Cordell	879
Suisun Bay, Cordelia, Suisun, and Montezuma Creeks	do	1-20,000	1867	do	948
Suisun Bay with confluence of Sacramento and San Joaquin Rivers.	do	1-20,000	1866-'7	do	905
Sacramento and San Joaquin Rivers	do	1-10,000	1867	do	935
Ballenas Bay and Duxbury Reef	do	1-10,000	1854	James Alden, U. S. N	438
Point Reyes and Drake's Bay	do	1-10,000	1854	do	435
Drake's Bay	do	1-40,000	1860	do	720
Off-shore soundings from Point Reyes to Bodega Head	do	1-100,000	1866	E. Cordell	889
Off-shore soundings from Point Reyes to Tomales Point	do	1-20,000	1866	do	890
Tomales Bay, entrance and part of	do	1-10,000	1861	B. F. Sands, U. S. N	756
Tomales Bay, from Tom's Point to head of navigation	do	1-10,000	1861	do	757
Bodega Bay, roadstead from Bodega Head to Tomales Point.	do	1-10,000	1862	do	806
Mendocino Bay	do	1-10,000	1872	L. A. Sengteller	1228
Mendocino City Harbor (reconnaissance)	do	1-10,000	1853	James Alden, U. S. N	384
Shelter Cove (reconnaissance)	do	1-10,000	1853	do	385
Blunt's Reef, off Cape Mendocino	do	1-10,000	1872	G. Bradford	1150
Humboldt Bay, entrance and part of	do	1-10,000	1859	James Alden, U. S. N	710
Humboldt Bay	do	1-10,000	1851	do	270
Humboldt Bay	do	1-10,000	1851	do	271
Humboldt Bay (Nos. 1 and 2)	do	1-10,000	1871	G. Farquhar	1176 a b

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Humboldt Bay (No. 3)	California	1-10,000	1871	G. Farquhar	1177 *a*
Humboldt Bay, bar, entrance, and approaches to	do	1-10,000	1871	do	1177 *b*
Trinidad Bay	do	1-5,000	1851	James Alden, U. S. N	274
Trinidad Harbor	do	1-10,000	1872	G. Bradford	1157
Crescent City Harbor and approaches	do	1-10,000	1859	James Alden, U. S. N	690
Crescent City Harbor (resurvey)	do	1-10,000	1855	do	480
Crescent City Harbor	do	1-10,000	1853	do	383
Crescent City Reef	do	1-20,000	1869	A. W. Chase	1025 *a*
Rock Ledge, examination of	do	1-10,000	1871	do	1025 *b*
Crescent City Reef to False Klamath	do	1-20,000	1873-'4	H. C. Taylor, U. S. N	1236
Crescent City Reef to Smith's River	do	1-20,000	1873-'4	do	1237
Coast from Smith's River to Barnacle Rock, Oregon	do	1-20,000	1874	do	1239
Coast from False Klamath to Columbia River	do		1854	James Alden, U. S. N	402
Coast from Table Bluff, Cal., to Coquille River, Oregon	California and Oregon.		1850	W. P. McArthur, U. S. N	242
Chetko Cove	Oregon	1,10,000	1873	P. C. Johnson, U. S. N	1212 *a*
Hunter's Cove	do	1,10,000	1873	do	1212 *b*
Coast from Goat Island to Mack's Arch	do	1,20,000	1874	H. C. Taylor, U. S. N	1240
Port Orford or Ewing Harbor	do	1-10,000	1853	James Alden, U. S. N	381
Coquille River, entrance and part of (reconnaissance)	do	1-10,000	1860	do	722
Koos Bay, entrance and part of	do	1-10,000	1861	J. S. Lawson	755
Koos Bay	do	1-10,000	1865	do	901
Koos Bay	do	1-10,000	1865	do	902
Umpquah River entrance	do	1-10,000	1853	James Alden, U. S. N	382
Coast from Umpquah Head to Columbia River	do		1851	W. P. McArthur, U. S. N	240
Yaquina Bay	do	1-10,000	1868	A. W. Chase	998
Tillamook Bay	do	1-10,000	1866-'7	J. Kincheloe	936
Nehalem River entrance	do	1-5,000	1868	E. Cordell, G. Farquhar	973
Columbia River entrance	do	1-20,000	1850	W. P. McArthur, U. S. N	250
Columbia River entrance	do	1-20,000	1851	do	273
Columbia River entrance	do	1-20,000	1854	James Alden, U. S. N	428
Columbia River entrance	do	1-20,000	1852	do	336
South Channel Bar, mouth of Columbia River	do	1-10,000	1854	do	429
Columbia River entrance	do	1-20,000	1868	E. Cordell	1019
Columbia River, from Three-Tree Point to Gray's Bay	do	1-10,000	1867-'8	do	1015
Columbia River, from Cathlamet Head to Settlers' Point	do	1-10,000	1868	do	1016
Columbia River, from Settlers' Point to Tongue Point	do	1-10,000	1868	do	1017
Columbia River, from Tongue Point to Cape Disappointment	do	1-20,000	1868	do	1018
Coast from Columbia River to Point Grenville, Washington Territory	do		1852	James Alden, U. S. N	334
Coast from Columbia River to Admiralty Inlet, Washington Territory	do		1852	do	333
Coast from Columbia River to Cape Flattery	Washington Ter		1852	do	427
Shoalwater Bay	do	1-18,818	1855	do	498
Shoalwater Bay	do	1-20,000	1852	do	335
Entrance and part of Gray's Harbor	do	1-20,000	1862	J. S. Lawson	809
Grenville Harbor	do	1-10,000	1854	James Alden, U. S. N	426
Destruction Island and vicinity	do	1-10,000	1856	J. S. Lawson	886
Nee-ah Harbor, Straits of Juan de Fuca	do	1-10,000	1852	James Alden, U. S. N	337
False Dungeness, Straits of Juan de Fuca	do	1-10,000	1852	do	325
False Dungeness, Straits of Juan de Fuca	do	1-10,000	1855	do	500
Port Townshend	do	1-10,000	1854	do	434
Port Ludlow, entrance of Hood's Canal	do	1-10,000	1855	do	508
Admiralty Inlet	do	1-100,000	1855	do	510
Port Gamble, entrance of Hood's Canal	do	1-10,000	1855	do	509
Port Madison	do	1-10,000	1868	J. S. Lawson	1102
Blakely Harbor	do	1-10,000	1856	James Alden, U. S. N	525
Duwamish Bay	do	1-10,000	1854	do	432
Steilacoom Harbor and vicinity of Puget's Sound	do	1,10,000	1855	do	499
Olympia Harbor, Puget Sound	do	1-10,000	1855	do	507
Partridge Bank, Strait of Juan de Fuca	do	1-20,000	1871	J. S. Lawson	1130
Lawson Reef, Rosario Straits	do	1,10,000	1871	do	1129

APPENDIX No. 8—Continued.

Localities.	State.	Scale.	Date.	Hydrographer.	Registered number.
Smith's or Blunt's Island, Rosario Straits	Washington Ter.	1-10,000	1854	James Alden, U. S. N.	431
Haro and Rosario Straits, south entrances	....do		1853	......do	405
Rosario and Haro Straits, south entrances	....do	1-100,000	1854	......do	433
Haro and Rosario Straits, north entrances	....do	1-20,000	1858	......do	708
Gulf of Georgia, and north entrances to Haro and Rosario Straits.	....do	1-100,000	1858-'9	......do	709
Bellingham Bay	....do	1-20,000	1855	......do	502
Semi-ah-moo Bay	....do	1-20,000	1857	R. M. Cuyler, U. S. N.	603

APPENDIX No. 9.

REPORT ON THE TELEGRAPHIC DETERMINATION OF THE LONGITUDE OF KEY WEST, BY CHARLES A. SCHOTT, ASSISTANT IN THE COAST SURVEY.

Dear Sir: In compliance with your direction, a second computation and revision of the difference of longitude between Washington and Key West has been made, and the following report on the results is herewith respectfully submitted:

INTRODUCTION.

The trigonometrical survey of the islands and reefs skirting the southern shore of Florida has depended, since 1849, for its standard longitude on a number of moon-culminations and on a chronometric determination—means which it was desirable to have superseded by the more accurate method of employing the electric telegraph. This would afford a check on the old work, and furnish a precise determination of the longitude of an extreme southern point of the triangulation, both for the immediate use of the Coast Survey as well as, prospectively, for the extension of the telegraphic system of longitudes over the regions of the Gulf and Caribbean Sea.

The telegraphic determination of the longitude between Washington and Key West was executed jointly by the United States Coast Survey and the United States Naval Observatory, and under the direction of their respective superintendents. The observations at the Naval Observatory were made by Profs. W. Harkness and J. R. Eastman, U. S. N., and Assistant Observer E. Frisby; those at Key West by Subassistant Edwin Smith, United States Coast Survey. Professor Eastman made the computation of the transits at Washington, the results of which were communicated by Rear-Admiral C. H. Davis, Superintendent, under date of November 6, 1874; a second computation was made by myself; the first computation of the transits at Key West was made by the observer and by Prof. R. Keith, of the United States Coast Survey, and the second computation by Mr. James Main, of the Computing Division, Coast Survey Office.

The arrangement for the telegraphic connection of the two stations was made by G. W. Dean, Assistant in the Coast Survey. The Survey is indebted to General Thomas T. Eckert, general superintendent of the Western Union Telegraph, for facilities given while using the line.

Automatic and arbitrary signals were transmitted by means of break-circuit arrangements. Exchanges took place on seven nights between the dates December 24, 1873, and January 11, 1874.

DESCRIPTION OF OBSERVING-STATIONS AND OF INSTRUMENTAL OUTFIT.

The station at *Washington* is the site of the transit-circle, 77.8 feet, or $0^s.066$, west of the center of the dome of the Observatory. This instrument is in latitude $+38^\circ 53' 38''.8$, and in longitude $5^h 08^m 12^s.16$ west of Greenwich, as determined, by means of transatlantic cables, in 1866, 1870, and 1872. A description of this transit-circle, made by Pistor and Martins, of Berlin, is contained in the Washington Observations for 1865; a briefer account of it is found in the introduction to the Washington Observations for 1873 (p. xviii and following). It suffices here to state that the telescope has a clear aperture of $8\frac{1}{2}$ inches, and a focal length of 145 inches nearly; the magnifying power habitually used is 186 diameters. Of subsidiary apparatus connected with it, there are a pair of collimators mounted in the meridian of the instrument and placed within the observing-room. The position of the axis is reversed at the beginning of each calendar year, and the line of collimation is determined at suitable intervals. During 1873, the clamp-end was east; during 1874, it was west; a reversal therefore took place while the longitude work was in progress, a circum-

stance which could only be favorable to the accuracy of the result. The standard sidereal clock, made by Kessels, of Altona, is in electric connection with a barrel-chronograph, the speed of which is regulated by a Hipp vibrating spring. The beats of the clock are registered in consequence of the pendulum making contact through a globule of mercury. The chronograph works with one pen, recording automatic and arbitrary signals, and revolves once each minute. The electro-magnetic apparatus used for sending and receiving longitude-signals is entirely automatic. (See description in the Washington Observations for 1867, Appendix 1.)

At *Key West, Fla.*, the Coast Survey established a temporary observing-station in front of the United States naval depot. It is marked by a brick pier, 24 feet north and 6 feet west of the center of the soldiers' monument in Clinton Place. The pier was left standing; it is capped with a flagstone having a cross-cut marking its center. This site is also 471.50 feet south and 295.04 feet east of Tift's Observatory, or lookout, one of the trigonometrical stations of the Survey, hence position of astronomical station, in latitude 24° 33′ 26″.5 and in approximate longitude $5^h\ 27^m\ 13^s.84$ west of Greenwich.

The transit-instrument was one of the pattern known as meridian telescope (No. 13 of the Survey); it has a clear aperture of 1¾ inches, and a focal length of 26 inches. The maker, Mr. W. Würdemann, states that, with the diagonal eye-piece, the magnifying power is about 70 diameters. The eye-piece has no parallactic motion, in consequence of which only the three inner tallies of the glass diaphragm were used at Key West. The horizontality of the axis was ascertained by means of a striding-level; the pivot inequality is very small. In connection with the instrument, there was used a Hipp fillet-chronograph, Coast Survey No. 5, using one pen, and two break-circuit sidereal chronometers, Frodsham No. 3477, as standard chronometer, and Parkinson & Frodsham No. 2795, as an auxiliary instrument. No. 3477 beats half-seconds and breaks every second; No. 2795 beats four-tenths of a second and breaks every even second. The observer remarks that the instrument did not prove quite as steady as expected; it is ascribed to the immediate proximity of the sea, and to its small (a few feet) elevation above its level.

RELATIVE PERSONAL EQUATIONS.

The observations for personal equation are meager, and not of a very satisfactory character. The preparations which were then in progress for observing the transit of Venus were interfering, to a considerable extent, with a more precise determination of the personal equations between the several observers. The observers are indicated by the initial letters of their names.

The following three equations were taken from the volume of the Washington Observations for 1873, p. lii of introduction. Since they refer to clock-*correction*, the signs of the constants have been changed, in order to refer them directly to clock-time, which is the thing *actually* observed or noted:

July 30, 1873, $0 = +\,0^s.18 + H - F$
Sept. 30, 1873, $0 = -\,0^s.06 + E - F$
Nov. 5, 1873, $0 = +\,0^s.16 + H - E$

The following equation was derived from transit-observations at the United States Naval Observatory, each observer using his own instrument.* A correction for small difference of meridians was applied, and the personal equation refers, as above, to clock-time:

April 27, 29, May 3, 11, 1874, $0 = -\,0^s.11 + E - S$

Observations made by H about this time led to no satisfactory results.

The following two equations are the results of comparisons made with a portable personal-equation apparatus† at the Coast Survey Office:

May 20, 1874 . . . $0 = +\,0^s.07 + F - S$
May 20, 21, 1874 $0 = -\,0^s.01 + E - S$

* This method has two drawbacks: first, its excessive labor, both of observing and computing; secondly, its indirectness, by necessarily including or mixing up with the quantity sought a number of so-called instrumental constants.

† Observations made April 8, 9, 10, 1874, with an inferior apparatus, are not introduced.

Now, referring for convenience all observations to the Key West observer, as standard observer, we put S = 0, and form the following normal equations:

$$0 = +0.34 + 2\,H - 1\,F - 1\,E$$
$$0 = -0.05 - 1\,H + 3\,F - 1\,E$$
$$0 = -0.34 - 1\,H - 1\,F + 4\,E$$

$$\text{Whence}\begin{cases} H = -0^s.164 \\ F = -0^s.025 \\ E = +0^s.038 \end{cases} \quad \text{and} \begin{cases} S = H + 0^s.164 \pm 0^s.040 \\ S = F + 0^s.025 \quad 0^s.035 \\ S = E - 0^s.038 \quad 0^s.030 \end{cases}$$

which corrections have been applied *directly* to the indicated clock-times of the Washington observers,* as seen further on. The above probable errors are mere approximations.

METHOD OF REDUCTION OF OBSERVATIONS FOR LOCAL TIME.

Referring, in general, for notation and method of reduction of transits to Coast Survey Reports for 1866, 1868, and 1872,† it suffices to state that, for the observations with the Washington transit-circle, the corrections to the observed clock-time for level, collimation, and personal equation were applied at once. Conditional equations and normal equations were then formed for the determination of the clock-rate, the azimuthal deviation, and the final clock-correction. Weights were introduced, depending on the number of wires observed, and upon the star's declination.

EQUATORIAL INTERVALS OF STANDARD SET OF WIRES OF THE TRANSIT-CIRCLE.

The following values are taken from Table II, on page xxix of the Washington Observations for 1873; the intervals refer to clamp east and to the nine wires habitually used.

Wires.	Equatorial intervals.	
	s.	s.
I or B_1	+ 12.255	
II or B_2	+ 9.708	
III or B_3	+ 8.183	
IV or C_2	+ 2.049	C_1 + 4.095
V or C_3	— .004	
VI or C_4	— 2.058	
VII or D_1	— 8.181	C_5 — 4.102
VIII or D_2	— 9.685	
IX or D_4	— 12.263	

The pivots of the instruments are sensibly round and equal in diameter (p. xxxviii, Obs. of 1873); the value of one division of the hanging level equals $0^s.058$ (p. xxxviii). The collimation-correction includes the term $\pm 0^s.021 \cos \varphi \sec \delta$, representing the effect of the diurnal aberration. The level-constants b and the collimation-constants c for the dates in 1873 are taken from page lxxxiv, Obs. of 1873, and from a MS. communication for dates in 1874. They are as follows:

1873.	*b.*	*c.*
	s.	s.
Dec. 24	+ .74	— .13
Dec. 26	+ .74	— .12
Dec. 30	+ .74	— .12
Dec. 31	+. 74	— .10
1874.	Circle reversed.	
Jan. 9	+1.10	.00
Jan. 1	+1.08	+ .02
Jan. 11	+ .88	+ .05

* Professor Harkness remarked that he observes habitually about a quarter of a second earlier than Professor Eastman, a statement sufficiently borne out by the above equations, which make $H = E - 0^s.20$. It is also stated that several series of observations indicate that Professor Eastman and Mr. Frisby have approximately the same personal equation.

† These and other papers on latitudes and azimuths have lately been reprinted (March, 1876) under one cover and under the title "Professional Papers."

The weights to broken transits are computed from formulæ given in Coast Survey Report for 1872, Appendix No. 12. They are:

Number of wires observed.	Weight for transit-circle.	Weight for meridian telescope.	Number of lines* observed.
1	.45	.41	1
2	.65	.61	2
3	.77	.73	3
4	.83	.80	4
5	.89	.86	5
6	.93	.91	6
7	.96	.95	7
8	.98	.98	8
9	1.00	1.00	9

To determine the clock-correction $\triangle T_0$ for an assumed middle epoch T_0, the azimuthal deviation, and the clock-rate, we obtain, from the general expression $\alpha = T + \triangle t + r(\alpha - T_0) + a\,A + b\,B + c\,C$, by putting $t = T + b\,B + c\,C$ and $\triangle T_0 = \triangle T + \delta T$, where δT is a correction to an approximate value $\triangle T$, the form of the conditional equations:

$$\delta T + a\,A + r\,(\alpha - T_0) = \alpha - t - \triangle T$$

Besides the weights introduced from number of wires observed, each of these expressions is specially weighted, depending on the declination of the star. These latter weights, p, are taken from the table given in Appendix No. 12, Coast Survey Report of 1872 (p. 223); they are deduced from the expression of the probable errors of observation—

$$\varepsilon = \sqrt{(0.063)^2 + (0.036)^2 \tan^2 \delta} \text{ and } \varepsilon = \sqrt{(0.080)^2 + (0.063)^2 \tan^2 \delta}$$

for large and small transit-instruments, respectively. Normal equations are then formed, from which result the values of δT, a, and r.

In the case of the Key West observations, they are reduced by the method explained in the Report of 1872 (p. 225); the stars observed with clamp W are treated by themselves, and furnish two normal equations determining δT and $a_{,}$; similarly the stars observed with clamp E give two normal equations determining δT and $a_{,,}$; now for the same middle epoch T_0, the two values found for δT must be identical; if not, small changes in assumed values of r and c must be introduced until they become identical. Each night's work, therefore, furnishes two sets of normal equations. The conditional equations were weighted as before, but, to save space, are not given here. The correction for diurnal aberration is introduced by itself. The equatorial intervals of the lines of meridian-telescope No. 13 are as follows: For clamp west

Lines.	Equatorial intervals.
	s.
C_1	+18.79
C_2	14.48
C_3	10.51
D_1	4.36
D_2	+0.08
D_3	−4.23
E_1	10.59
E_2	14.67
E_3	−18.73

The value of one division of the striding-level B equals 1″.01 as determined by means of a level-trier at the Coast Survey Office in 1872. The pivot inequality has been ascertained from three sets of observations taken August 29, 1873, at Colorado Springs, Colo., and March 21, 1874, at Atlanta, Ga., which give for clamp west

$$p = +\,0^s.006 \pm 0^s.002$$

The effect of this is included in the level-correction.

* Ruled on a glass diaphragm, and comprising tallies C 1, 2, 3, D 1, 2, 3, and E 1, 2, 3. Tallies B and F are not used; they appear blurred in consequence of a want of parallactic motion.

The following table contains the adopted mean places in right ascension for 1873 or 1874 of the stars observed at both places. They are those taken from the American Ephemeris, with corrections from Table C, p. lxxxv, Washington Observations of 1873. The correction of ι Cassiopeæ is from the catalogue of the Astronomische Gesellschaft, and of 22 Camelopardalis from the same catalogue combined with the two Greenwich seven-year catalogues.

Adopted mean places in right ascension of stars observed at Washington and Key West.

Star.	American Ephemeris 1873.0.			American Ephemeris 1874.0.			Correction by N. O.	Correction additional.
	h.	m.	s.	h.	m.	s.	s.	s.
ε Piscium	0	56	21.20				+ .02	
α Ursæ Minoris	1	12	18.73					
θ' Ceti		17	40.54	1	17	43.54	+ .02	
38 Cassiopeæ		21	48.70		21	53.06		
η Piscium		24	41.32		24	44.52	+ .07	
o Piscium		38	41.40		38	44.56	− .03	
β Arietis		47	37.64		47	40.94	+ .02	
50 Cassiopeæ		52	37.91		52	42.89		
α Arietis	2	00	01.05	2	00	04.42	+ .01	
ξ' Ceti		06	16.17		06	19.34	+ .04	
ι Cassiopeæ		18	37.67		18	42.51		+ .03
ξ'' Ceti		21	24.47		21	27.65		
5 Ursæ Minoris	14	27	49.19					
γ Ceti	2	36	43.29		36	46.39	.00	
α Ceti		55	38.52		55	41.65	+ .02	
48 Cephei	3	04	17.26	3	04	24.61		
ζ Arietis		07	36.27		07	39.71	− .04	
α Persei		15	15.87		15	20.12		
δ Persei		33	53.29		33	57.53		
Tauri		39	56.25		39	59.81	.00	
ζ Persei		46	09.14		46	12.90	− .01	
γ' Eridani		52	06.27		52	09.07	+ .04	
γ Tauri	4	12	34.05	4	12	37.46	.00	
ε Tauri		21	12.14		21	15.64	− .01	
α Tauri		28	38.10		28	41.53	− .02	
9 Camelopardalis		41	26.18		41	32.10		
ι Aurigæ		48	43.51		48	47.41	− .04	
11 Orionis		57	18.85		57	22.27	− .07	
α Aurigæ	5	07	18.60	5	07	23.02		
β Orionis		08	26.10		08	28.98	.00	
β Tauri		18	15.88		18	19.66	− .02	
966 Groombridge		22	45.64		22	53.63		
δ Orionis	5	25	31.17		25	34.23	− .03	
α Leporis		27	07.82		27	10.47	− .04	
ε Orionis	5	29	46.18		29	49.22	− .01	
α Columbæ		35	03.10	5	35	05.27	− .04	
α Orionis	5	48	17.81	5	48	21.06	− .03	
22 Camelopardalis	6	04	50.70	6	04	57.31		+ .13
δ Ursæ Minoris	18	13	18.15	18	12	58.74		
μ Geminorum	6	15	16.66	6	15	20.29	− .04	
γ Geminorum	6	30	22.52	6	30	25.99	− .03	
α Canis Majoris	6	39	33.06	6	39	35.71	− .08	
51 Cephei	6	40	13.92	6	40	44.18		
ε Canis Majoris	6	53	38.16	6	53	40.52	− .05	
δ Canis Majoris	7	03	13.71	7	03	16.15	− .05	
δ Geminorum	7	12	32.25	7	12	35.84	− .06	
α^2 Geminorum				7	26	33.21	+ .24	
α Canis Majoris				7	32	42.41	− .16	
β Geminorum				7	37	36.23	− .03	

PROBABLE ERROR OF CLOCK-CORRECTIONS.

The probable error of a resulting clock-correction from transits of a single star over nine wires, and referred to the equator, is found by

$$\varepsilon = 0.675\sqrt{\frac{\Sigma(\Delta p)^2}{[m]-[\mu]}}$$

and of a resulting clock-correction from a number of stars in a set $\varepsilon_0 = \varepsilon\sqrt{q}$, where q is found by means of the usual weight-equations.† m equals the number of stars in a set; $[m]$, the number of stars in all sets; and μ the number of unknown quantities in a set of normal equations, and $[\mu]$ their sum total. For the Washington observations we have—

$$\Sigma(\Delta p)^2 = .1054$$
$$[m] = 57$$
$$[\mu] = 20$$

hence,

$$\varepsilon = \pm\, 0^s.036$$

For the Key West observations, we have—

$$\Sigma(\Delta p)^2 = .4344$$
$$[m] = 143$$
$$[\mu] = 36$$

hence,

$$\varepsilon = \pm\, 0^s.043^*$$

The probable errors of the resulting clock and chronometer corrections on each night are given further on.

WASHINGTON, UNITED STATES NAVAL OBSERVATORY.

Reduction of transits of stars for clock-correction.

DECEMBER 24, 1873.—*E. Frisby, observer.—Transit-circle, clamp east.*

Star.	Clock-time over mean of wires.	Red. to m. of wires.	Corr. for p. eq.	Level corr. b B	Coll. corr. c C	Corr. for rate. r	Azim. corr. a A	Seconds of obs'd trans.	Seconds of app't R. A.	Clock corr. ΔT_0	Diff. Δ	Equat'l diff. $p\Delta$
	h. m. s.	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
α Arietis	1 59 56.83	.00	+ .02	+ .77	− .14	− .00	− .07	57.41	64.14	+ 6.73	− .05	− .05
ξ^1 Ceti	2 06 12.11	....	+ .02	+ .64	− .13	− .01	− .12	12.51	19.21	+ 6.70	− .02	− .02
ι Cassiopeæ	18 34.25	− .01	+ .02	+ 1.66	− .33	− .03	+ .28	35.8	42.4	....	....	+ .05
5 Ursæ Minoris, S. P	27 42.36	....	....	− 1.32	+ .55	− .05	− .89	40.6	47.2	....	....	+ .02
γ Ceti	2 36 39.47	....	+ .02	+ .60	− .13	− .06	− .14	39.76	46.43	+ 6.67	+ .01	+ .01
DECEMBER 26, 1873.—*J. R. Eastman, observer.—Transit-circle, clamp east.*												
γ Tauri	4 12 31.50	....	− .04	+ .70	− .12	+ .04	− .12	31.96	37.81	+ 5.85	− .03	− .03
ε Tauri	21 09.73	....	− .04	+ .73	− .13	+ .03	− .10	10.22	16.00	+ 5.78	+ .04	+ .04
α Tauri	28 35.69	....	− .04	+ .71	− .13	+ .02	− .12	36.13	41.92	+ 5.79	+ .03	+ .03
β Orionis	5 08 23.70	....	− .04	+ .51	− .12	− .01	− .22	23.82	29.62	+ 5.80	+ .02	+ .02
β Tauri	18 13.80	....	− .04	+ .83	− .14	− .01	− .06	14.38	20.21	+ 5.83	− .01	− .01
δ Orionis	25 28.70	....	− .04	+ .58	− .12	− .02	− .18	28.92	34.80	+ 5.88	− .06	− .06
ε Orionis	29 43.80	....	− .04	+ .57	− .12	− .02	− .19	44.00	49.83	+ 5.83	− .01	− .01
α Orionis	48 15.58	....	− .04	+ .64	− .12	− .04	− .15	15.87	21.62	+ 5.75	+ .07	+ .07
δ Ursæ Minoris, S. P	6 11 39.75	+ 63.64	....	− 7.25	+ 2.03	− .06	− 3.99	34.1	39.9	......	....	.00

* In the determination of the telegraphic difference of longitude between New Orleans and Galveston two other Coast Survey observers gave $\varepsilon = \pm\, 0^s.054$ and $\pm\, 0^s.055$, using transit-instruments of 46 inches focal length.

† $[aa]\,q + [ab]\,q_{\text{I}} + [ac]\,q_{\text{II}} + \ldots = +1$

$$[ab] + [bb] + [bc] = 0$$
$$[ac] + [bc] + [cc] = 0$$

Reduction of transits of stars for clock-correction—Continued.

DECEMBER 30, 1873.—*J. R. Eastman, observer.—Transit-circle, clamp east.*

Star.	Clock-time over mean of wires.	Red. to m. of wires.	Corr. for p. eq.	Level corr. bB	Coll. corr. cC	Corr. for rate. r	Azim. corr. $a A$	Seconds of obs'd trans.	Seconds of app't R. A.	Clock corr. ΔT_0	Diff. Δ	Equat'l diff. $p\Delta$
	h. m. s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
11 Orionis	4 57 17.60	....	− .04	+ .70	− .12	+ .01	− .13	18.02	22.71	+ 4.69	− .06	− .06
β Orionis	5 08 24.93	....	− .04	+ .51	− .12	+ .01	− .24	25.05	29.63	+ 4.58	+ .05	+ .05
α Orionis	48 16.80	....	− .04	+ .64	− .12	.00	− .17	17.11	21.65	+ 4.54	+ .09	+ .09
δ Ursæ Minoris, S. P	6 12 45.00	+ .04	....	− 7.25	+ 2.03	.00	− 4.36	35.5	39.8	....	....	.00
μ Geminorum	15 15.73	....	− .04	+ .77	− .13	.00	− .10	16.23	20.94	+ 4.71	− .08	− .08
γ Geminorum	30 21.59	....	− .04	+ .71	− .13	.00	− .13	21.99	26.64	+ 4.65	− .02	− .02
51 Cephei	40 51.20	− .04	....	+ 10.21	− 2.49	.00	+ 4.91	63.8	67.2	....	....	+ .01
ε Canis Majoris	6 53 37.01	....	− .04	+ .32	− .13	− .01	− .33	36.82	41.44	+ 4.62	+ .01	+ .01
δ Canis Majoris	7 03 12.50	....	− .04	+ .35	− .13	− .01	− .32	12.44	17.01	+ 4.57	+ .06	+ .06
δ Geminorum	12 31.34	....	− .04	+ .77	− .13	− .01	− .10	31.83	36.50	+ 4.67	− .04	− .04

DECEMBER 31, 1873.—*J. R. Eastman, observer.—Transit-circle, clamp east.*

Star.	Clock-time over mean of wires.	Red. to m. of wires.	Corr. for p. eq.	Level corr. bB	Coll. corr. cC	Corr. for rate. r	Azim. corr. $a A$	Seconds of obs'd trans.	Seconds of app't R. A.	Clock corr. ΔT_0	Diff. Δ	Equat'l diff. $p\Delta$
ε Piscium	0 56 18.59	....	− .04	+ .63	− .10	+ .02	− .23	18.87	23.72	+ 4.85	− .08	− .08
α Ursæ Minoris	1 11 52.10	− .09	....	+ 20.18	− 4.22	+ .02	+ 14.08	22.1	26.7	....	....	.00
θ' Ceti	17 38.40	....	− .04	+ .51	− .10	+ .01	− .33	38.45	43.21	+ 4.76	+ .01	+ .01
η Piscium	24 38.93	....	− .04	+ .70	− .10	+ .01	− .19	39.31	44.08	+ 4.77	.00	.00
β Arietis	47 35.33	....	− .04	+ .75	− .11	.00	− .15	35.78	40.55	+ 4.77	.00	.00
α Arietis	1 59 58.84	....	− .04	+ .77	− .11	.00	− .13	59.33	64.08	+ 4.75	+ .02	+ .02
ξ' Ceti	2 06 14.20	....	− .04	+ .64	− .10	.00	− .23	14.47	19.16	+ 4.69	+ .08	+ .08
11 Orionis	4 57 17.58	....	− .04	+ .70	− .10	− .06	− .18	17.90	22.71	+ 4.81	− .04	− .04
α Aurigæ	5 07 18.10	....	− .04	+ 1.06	− .14	− .07	+ .08	18.89	23.76	+ 4.77	.00	.00
β Orionis	5 08 35.07	− 10.15	− .04	+ .51	− .10	− .07	− .32	24.90	29.64	+ 4.74	+ .03	+ .03

JANUARY 9, 1874.—*W. Harkness, observer.—Transit-circle, clamp west.*

Star.	Clock-time over mean of wires.	Red. to m. of wires.	Corr. for p. eq.	Level corr. bB	Coll. corr. cC	Corr. for rate. r	Azim. corr. $a A$	Seconds of obs'd trans.	Seconds of app't R. A.	Clock corr. ΔT_0	Diff. Δ	Equat'l diff. $p\Delta$
γ Geminorum	6 30 19.61	....	+ .16	+ 1.06	.00	+ .03	+ .34	21.20	26.73	+ 5.53	+ .01	+ .01
α Canis Majoris	39 29.34	....	+ .16	+ .65	.00	+ .02	+ .73	30.90	36.43	+ 5.53	+ .01	+ .01
51 Cephei	41 43.00	− 42.48	....	+ 15.17	.00	+ .02	− 13.20	02.5	08.0	....	....	.00
δ Geminorum	7 12 20.25	+ 9.24	+ .16	+ 1.14	.00	− .01	+ .26	31.04	36.65	+ 5.61	− .07	− .07
α^2 Geminorum	26 27.32	.00	+ .16	+ 1.29	.00	− .03	+ .12	28.86	34.44	+ 5.58	− .04	− .04
α Canis Minoris	32 35.99	....	+ .16	+ .92	.00	− .03	+ .47	37.51	43.05	+ 5.54	.00	.00
β Geminorum	37 30.16	....	+ .16	+ 1.23	.00	− .04	+ .18	31.69	37.15	+ 5.46	+ .08	+ .07

JANUARY 10, 1874.—*W. Harkness, observer.—Transit-circle, clamp west.*

Star.	Clock-time over mean of wires.	Red. to m. of wires.	Corr. for p. eq.	Level corr. bB	Coll. corr. cC	Corr. for rate. r	Azim. corr. $a A$	Seconds of obs'd trans.	Seconds of app't R. A.	Clock corr. ΔT_0	Diff. Δ	Equat'l diff. $p\Delta$
α Orionis	5 48 14.71	....	+ .16	+ .93	+ .02	− .04	+ .33	16.11	21.71	+ 5.60	− .04	− .04
22 Camelopardalis	6 04 52.40	− .01	+ .16	+ 2.64	+ .06	− .02	− .91	54.32	59.94	+ 5.62	− .06	− .02
δ Ursæ Minoris, S. P	11 47.28	+ 49.55	....	− 10.59	− .34	− .01	+ 8.72	34.6	39.9	....	....	.00
μ Geminorum	15 24.90	− 10.88	+ .16	+ 1.12	+ .02	− .01	+ .19	15.50	21.03	+ 5.53	+ .03	+ .03
γ Geminorum	30 19.74	....	+ .16	+ 1.04	+ .02	.00	+ .25	21.21	26.74	+ 5.53	+ .03	+ .03
α Canis Majoris	39 29.60	....	+ .16	+ .64	+ .02	+ .01	+ .54	30.97	36.44	+ 5.47	+ .09	+ .09
ε Canis Majoris	6 53 34.53	....	+ .16	+ .47	+ .02	+ .02	+ .67	35.87	41.53	+ 5.66	− .10	− .10
δ Canis Majoris	7 03 10.12	....	+ .16	+ .51	+ .02	+ .03	+ .64	11.48	17.11	+ 5.63	− .07	− .07
δ Geminorum	12 29.61	....	+ .16	+ 1.12	+ .02	+ .04	+ .20	31.15	36.66	+ 5.51	+ .05	+ .05

JANUARY 11, 1874.—*W. Harkness, observer.—Transit-circle. clamp west.*

Star.	Clock-time over mean of wires.	Red. to m. of wires.	Corr. for p. eq.	Level corr. bB	Coll. corr. cC	Corr. for rate. r	Azim. corr. $a A$	Seconds of obs'd trans.	Seconds of app't R. A.	Clock corr. ΔT_0	Diff. Δ	Equat'l diff. $p\Delta$
α Columbæ	5 34 59.40	....	+ .16	+ .31	+ .06	+ .05	+ .36	60.34	66.35	+ 6.01	− .03	− .03
α Orionis	48 14.60	....	+ .16	+ .76	+ .05	+ .04	+ .16	15.77	21.71	+ 5.94	+ .04	+ .04
δ Ursæ Minoris, S. P	6 10 36.66	+ 122.54	....	− 8.63	− .84	+ .02	+ 4.27	34.0	40.0	....	....	.00
μ Geminorum	15 13.80	....	+ .16	+ .92	+ .05	+ .01	+ .09	15.03	21.03	+ 6.00	− .02	− .02
γ Geminorum	30 19.57	....	+ .16	+ .85	+ .05	.00	+ .12	20.75	26.74	+ 5.99	− .01	− .01
α Canis Majoris	39 29.50	....	+ .16	+ .52	+ .05	− .01	+ .27	30.49	36.44	+ 5.95	− .03	− .03
δ Geminorum	7 12 29.51	....	+ .16	+ .91	+ .05	− .04	+ .10	30.69	36.67	+ 5.98	.00	.00

Conditional equations and normal equations to preceding reduction.

Dec. 24, 1873 $T_0=2^h$ $\Delta T=+6^s.60$ $r=-0^s.100$

$.99\delta T+$	$.296a=$	$+.06$	and $p=$ .97
1.00	$+.515$	$-.02$	1.00
.94	-1.120	$+.21$	.36
1.00	$+3.809$	$-.93$	.16
1.00	$+.591$	$-.07$	1.00

$$+3.429\delta T+1.621a=-.110$$
$$+1.621\quad +3.472\quad -.686$$

s.

$a=-.234$

$\delta T=+.078$

Dec. 26, 1873 $T_0=5^h$ $\Delta T=+5^s.70$

$1.00\delta T+$	$.415a-$	$.79r=$	$+.07$	and $p=$ .99
1.00	.361	$-.64$	$+.01$	.98
1.00	.401	$-.52$	$-.01$	.99
1.00	.742	$+.14$	$-.13$	1.00
1.00	.206	$+.30$	$+.06$	.93
1.00	.633	$+.43$	$-.02$	1.00
1.00	.645	$+.50$	$-.08$	1.00
1.00	.527	$+.81$	$-.14$	1.00
.99	13.609	$+1.20$	$+3.93$	.011

$$+7.901\delta T+4.048a+.248r=-.288$$
$$+4.048\quad +4.179\quad +.605\quad -.783$$
$$+.248\quad +.605\quad +2.497\quad -.272$$

s.

$r=-.047$

$a=-.290$

$\delta T=+.116$

Dec. 30, 1873 $T_0=6^h$ $\Delta T=+4^s.50$

$1.00\delta T+$	$.416a-$	$1.05r=$	$+.07$	and $p=$ .99
1.00	$+.742$	$-.86$	$-.15$	1.00
1.00	$+.527$	$-.20$	$-.13$	1.00
.94	$+12.921$	$+.20$	-4.29	.011
1.00	$+.304$	$+.25$	$+.11$	.97
1.00	$+.397$	$+.51$	$+.02$	.99
.94	-14.574	$+.64$	$+3.61$	.007
1.00	$+1.055$	$+.89$	$-.22$	.92
1.00	$+1.011$	$+1.05$	$-.26$	.94
1.00	$+.310$	$+1.21$	$+.06$	.96

$$+7.786\delta T+4.625a+1.622r=-.494$$
$$+4.625\quad +6.646\quad +1.283\quad -1.531$$
$$+1.622\quad +1.283\quad +5.363\quad -.241$$

s.

$r=-.007$

$a=-3.17$

$\delta T=+.126$

Dec. 31, 1873 $T_0=2^h$ $\Delta T=+4^s.60$

$1.00\delta T+$	$.529a-$	$1.06r=$	$+.04$	and $p=$ 1.00
.94	-30.282	$-.75$	$+13.32$	.002
1.00	$+.748$	$-.71$	$-.16$	1.00
1.00	$+.424$	$-.59$	$-.01$	.99
1.00	$+.341$	$-.21$	$+.02$	.98
1.00	$+.299$	.00	$+.02$	.97
1.00	$+.515$	$+.10$	$-.14$	1.00
1.00	$+.416$	$+2.96$	$-.03$	.99
1.00	$-.174$	$+3.12$	$+.18$	.76
.88	$+.653$	$+2.76$	$-.22$	1.00

$$+8.466\delta T+3.633a+5.269r=-.292$$
$$+3.633\quad +3.938\quad +1.296\quad -1.149$$
$$+5.269\quad +1.296\quad +25.716\quad -.229$$

s.

$r=-.021$

$a=-.437$

$\delta T=+.167$

Jan. 9, 1874 $T_0=7^h$ $\Delta T=+5^s.70$

$1.00\delta T+$	$.397a-$	$.50r=$	$+.20$	and $p=$ .99
1.00	$+.859$	$-.34$	$+.58$	.99
.88	-13.644	$-.28$	-11.80	.007
.91	$+.282$	$+.19$	$+.15$	.96
.96	$+.132$	$+.42$	$-.03$	.89
1.00	$+.552$	$+.54$	$+.28$	1.00
1.00	$+.208$	$+.63$	$-.10$	.93

$$+5.531\delta T+2.264a+.817r=+.992$$
$$+2.264\quad +2.626\quad +.062\quad +1.871$$
$$+.817\quad +.062\quad +1.215\quad -.162$$

s.

$r=-.069$

$a=+.851$

$\delta T=-.159$

Jan. 10, 1874 $\quad T_0 = 6^h\ 30^m \quad \Delta T = +5^s.70$

$$\begin{array}{rrrrl}
1.00\delta T + & .527a & -.70r & = +\ .19 & \text{and } p = 1.00 \\
.94 & -\ 1.353 & -.39 & -\ .95 & .30 \\
.91 & +12.509 & -.26 & +7.55 & .011 \\
.88 & +\ .268 & -.22 & +\ .01 & .97 \\
1.00 & +\ .397 & .00 & +\ .08 & .99 \\
1.00 & +\ .859 & +.16 & +\ .32 & .99 \\
1.00 & +\ 1.055 & +.39 & +\ .65 & .92 \\
1.00 & +\ 1.011 & +.55 & +\ .60 & .94 \\
1.00 & +\ .310 & +.71 & +\ .05 & .96
\end{array}$$

$$\begin{array}{rrrr}
+6.825\delta T & +3.961a & +\ .715r & = +1.612 \\
+3.961 & +5.581 & +\ .945 & +3.047 \\
+\ .715 & +\ .945 & +1.517 & +\ .583
\end{array}$$

$$\begin{array}{rl}
 & s. \\
r & = +.054 \\
a & = +.635 \\
\delta T & = -.138
\end{array}$$

Jan. 11, 1874 $\quad T_0 6^h\ 30^m \quad \Delta T = +6^s.20$

$$\begin{array}{rrrrl}
1.00\delta T + & 1.155a & -.92r & = +\ .22 & \text{and } p = .87 \\
1.00 & +\ .527 & -.70 & -\ .06 & 1.00 \\
.94 & +12.921 & -.27 & +3.79 & .011 \\
1.00 & +\ .304 & -.25 & -\ .10 & .97 \\
1.00 & +\ .397 & .00 & -\ .09 & .99 \\
1.00 & +\ .859 & +.16 & +\ .01 & .99 \\
1.00 & +\ .310 & +.71 & -\ .16 & .96
\end{array}$$

$$\begin{array}{rrrr}
+5.790\delta T & +3.501a & -\ .906r & = -.159 \\
+3.501 & +4.343 & -1.058 & +.624 \\
-\ .906 & -1.058 & +1.797 & +.229
\end{array}$$

$$\begin{array}{rl}
 & s. \\
r & = -.058 \\
a & = +.310 \\
\delta T & = -.224
\end{array}$$

Synopsis of results for correction and rate of clock.

Date.		Epoch. T_0	Clock-correction. ΔT_0		Hourly rate. r
1873.		h.	s.	s.	s.
December	24	2 sidereal time.	+ 6.678	± 0.022	− .100
	26	5	+ 5.816	0.018	− .047
	30	6	+ 4.626	0.017	− .007
	31	2	+ 4.767	0.017	− .021
1874.					
January	9	7	+ 5.541	0.020	− .069
	10	6.5	+ 5.560	0.018	+ .054
	11	6.5	+ 5.976	0.021	− .058

The above probable error to the clock-correction does not include the uncertainty arising from variation in personal equation.

Apparently, the rate of the Kessels clock undergoes very rapid changes, especially noticeable January 9 and January 10, when the daily rate was almost zero, yet the hourly rate at the time of observation was large and of opposite sign on the two nights. Whether all of this is real or attributable in part also to diurnal changes in the condition of the instrument, especially in collimation at a time when the temperature changes rapidly, or to a diurnal variation in the observer's personal equation, cannot be decided from the present observations. The subject has received attention at the United States Naval Observatory.*

* The reader may be referred to Appendix III, Washington Observations for 1867 (printed in 1870). See also Appendix I, Washington Observations for 1867, note, p. 25. In the manuscript containing the results deduced at the observatory, hourly rates greater than those given above have been admitted.

KEY WEST, COAST SURVEY ASTRONOMICAL STATION.

Reduction of transits of stars for chronometer-correction.

Observer, Edwin Smith. Instrument, meridian telescope, Coast Survey No. 13.

DECEMBER 24, 1873. $r = -0^s.20$. $c = +0^s.16$ W. $T_0 = 3^h 38^m$ chronometer. $\Delta T = -1^h 00^m 22^s$.

Star.	Chron. time over mean of lines.	Red. to mean of lines.	Rate corr'n.	Level corr'n. b B	Coll'n. corr'n. c C	Diur'l. aberr'n.	Azim. corr'n. a A	Seconds of obs'd transit.	Seconds of app't R. A. a	Seconds of chron. corr'n. Δ T.	Diff. Δ	Equat'l diff. p Δ
CLAMP EAST.	h. m. s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
η Piscium	2 25 05.86	+ 0.58	+ 0.24	+ 0.06	− 0.16	− 0.02	+ 0.01	06.57	44.15	22.42	+ 0.04	+ 0.04
ο Piscium	39 06.66	....	+ 0.20	− .03	− .16	− .02	+ .02	06.67	44.21	22.46	+ .08	+ .08
50 Cassiopeæ	53 05.47	....	+ 0.15	− .18	− .51	− .06	− .14	04.73	42.41	22.32	− .06	− .01
α Arietis	3 00 26.59	....	+ 0.13	− .10	− .17	− .02	.00	26.43	04.14	22.29	− .09	− .08
ξ[1] Ceti	16 41.78	....	+ 0.07	− .10	− .16	− .02	+ .02	41.59	19.22	22.37	− .01	− .01
α Cassiopeæ	19 05.47	....	+ 0.06	− .16	− .41	− .05	− .10	04.81	42.35	22.46	+ .08	+ .02
ξ[2] Ceti	21 50.20	....	+ 0.05	− .10	− .16	− .02	+ .02	49.99	27.58	22.41	+ .03	+ .03
CLAMP WEST.												
α Ceti	56 04.16	....	− 0.06	− .14	+ .16	− .02	+ .07	04.17	41.78	22.39	+ .01	+ .01
48 Cephei	4 05 48.81	....	− 0.09	− .45	+ .73	− .09	− .71	48.20	25.77	22.43	+ .05	+ .01
ζ Arietis	08 02.11	....	− 0.10	− .18	+ .17	− .02	+ .01	01.99	39.73	22.26	− .12	− .11
α Persei	15 42.98	....	− 0.12	− .28	+ .25	− .03	− .13	42.67	20.27	22.40	+ .02	+ .01
γ[1] Eridani	52 32.17	....	− 0.25	− .14	+ .16	− .02	+ .13	32.05	09.63	22.42	+ .04	+ .04

DECEMBER 26, 1873. $r = -0^s.04$. $c = +0^s.55$ W. $T_0 = 3^h 26^m$ chronometer. $\Delta T = -1^h 00^m 27^s$.

Star.	Chron. time over mean of lines.	Red. to mean of lines.	Rate corr'n.	Level corr'n. b B	Coll'n. corr'n. c C	Diur'l. aberr'n.	Azim. corr'n. a A	Seconds of obs'd transit.	Seconds of app't R. A. a	Seconds of chron. corr'n. Δ T.	Diff. Δ	Equat'l diff. p Δ
CLAMP WEST.												
θ[1] Ceti	2 18 10.23	....	+ 0.04	− .12	+ 0.55	− .02	+ .27	10.95	43.26	27.69	+ .08	+ .08
38 Cassiopeæ	22 19.30	....	+ 0.04	− .27	+ 1.57	− .05	− .98	19.61	52.03	27.58	− .03	− .01
η Piscium	25 11.17	....	+ 0.04	− .13	+ 0.56	− .02	+ .09	11.71	44.13	27.58	− .03	− .03
ο Piscium	39 11.25	....	+ 0.03	− .12	+ 0.55	− .02	+ .13	11.82	44.19	27.63	+ .02	+ .02
β Arietis	48 07.66	....	+ 0.02	− .12	+ 0.58	− .02	+ .04	8.16	40.59	27.57	− .04	− .04
50 Cassiopeæ	53 09.79	....	+ 0.02	− .30	+ 1.76	− .06	− 1.14	10.07	42.31	27.76	+ .15	+ .03
α Arietis	3 00 31.12	....	+ 0.02	− .16	+ 0.60	− .02	+ 0.01	31.57	04.12	27.45	− .16	− .14
ξ[1] Ceti	06 46.33	....	+ 0.01	− .12	+ 0.55	− .02	+ 0.13	46.88	19.20	27.68	+ .07	+ .07
CLAMP EAST.												
ι Cassiopeæ	3 19 12.11	....	0.00	− .32	− 1.40	− .05	− 0.55	09.79	42.29	27.50	− 0.11	− .03
γ Ceti	37 14.56	....	− .01	− .17	− 0.55	− .02	+ 0.12	13.93	46.41	27.52	− .09	− .09
α Ceti	56 09.90	....	− .02	− .14	− 0.55	− .02	+ 0.12	09.29	41.77	27.52	− .09	− .09
48 Cephei	4 04 32.70	+ 24.56	− .02	− .42	− 2.50	− .09	− 1.14	53.09	25.67	27.42	− .19	− .02
ζ Arietis	08 08.24	....	− .03	− .16	− 0.59	− .02	+ 0.02	07.46	39.73	27.73	+ .12	+ .11
α Persei	15 49.23	....	− .03	− .21	− 0.85	− .03	− 0.21	47.90	20.25	27.65	+ .04	+ .02
δ Persei	34 23.71	+ 3.13	− .04	− .24	− 0.82	− .03	− 0.18	25.53	57.77	27.76	+ .15	+ .09

DECEMBER 30, 1873. $r = +0^s.07$. $c = +0^s.10$ W. $T_0 = 2^h 35^m$ chronometer (2795). $\Delta T = -1^s$.

Star.	Chron. time over mean of lines.	Red. to mean of lines.	Rate corr'n.	Level corr'n. b B	Coll'n. corr'n. c C	Diur'l. aberr'n.	Azim. corr'n. a A	Seconds of obs'd transit.	Seconds of app't R. A. a	Seconds of chron. corr'n. Δ T.	Diff. Δ	Equat'l diff. p Δ
CLAMP WEST.												
θ[1] Ceti	1 17 44.82	....	− .09	− .04	+ 0.10	− .02	+ 0.13	44.90	43.22	1.68	+ .04	+ .04
38 Cassiopeæ	[illegible] 21 53.89	....	− .09	− .09	+ 0.29	− .05	− 0.48	53.47	51.84	1.63	− .01	.00
η Piscium	24 45.69	....	− .08	− .05	+ 0.10	.02	+ 0.04	45.68	44.09	1.59	− .05	− .05
ο Piscium	38 45.72	....	− .07	− .02	+ 0.10	− .02	+ 0.06	45.77	44.15	1.62	− .02	− .02
β Arietis	47 42.09	....	− 06	+ .01	+ 0.11	− .02	+ 0.02	42.15	40.55	1.60	− .04	− .04
50 Cassiopeæ	52 44.24	....	− .05	− .04	+ 0.32	− .06	− 0.56	43.85	42.12	1.73	+ .09	+ .02
α Arietis	2 00 13.48	− 7.92	− .01	− .02	+ 0.11	− .02	+ 0.01	05.60	04.08	1.52	− .12	− .10
ξ[1] Ceti	06 20.82	....	− .03	− .02	+ 0.10	− .02	+ 0.06	20.91	19.17	1.74	+ .10	+ .10
CLAMP EAST.												
ι Cassiopeæ	18 44.49	....	− .02	− .05	− .25	− .05	− 0.32	43.80	42.16	1.64	.00	.00
γ Ceti	36 50.47	− 2.34	.00	− .02	− .10	− .02	+ .07	48.06	46.39	1.67	+ .03	+ .03
α Ceti	55 43.41	....	+ .02	− .04	− .10	− .02	+ .07	43.34	41.75	1.59	− .05	− .05
48 Cephei	3 04 28.27	....	+ .03	− .13	− .45	− .09	− .69	26.94	25.46	1.48	− .16	− .02
ζ Arietis	07 41.46	....	+ .03	− .05	− .11	− .02	+ .01	41.32	39.71	1.61	− .03	− .03
α Persei	15 22.18	....	+ .05	− .07	− .15	− .03	− .12	21.86	20.22	1.64	.00	.00
δ Persei	33 59.80	....	+ .07	− .07	− .15	− .03	− .11	59.51	57.75	1.76	+ .12	+ .07
η Tauri	40 01.69	....	+ .08	− .05	− .11	− .02	− .00	01.59	00.00	1.59	− .05	− .05
ζ Persei	46 15.02	....	+ .08	− .06	− .12	− .02	− .03	14.87	13.11	1.76	+ .12	+ .10
γ[1] Eridani	52 11.21	....	+ .09	− .04	− .10	− .02	+ .12	11.26	09.61	1.65	+ .01	+ .01

Reduction of transits of stars for chronometer-correction—Continued.

DECEMBER 30, 1873. $r = +0^s.07$. $c = +0^s.10$. $T_0 = 5^h\ 57^m$ chronometer. $\triangle T = -1^s$.

Star.	Chron. time over mean of lines.	Red. to mean of lines.	Rate corr'n.	Level corr'n. b B	Coll'n. corr'n. c C	Dinr'l. aberr'n.	Azim. corr'n. a A	Seconds of obs'd transit.	Seconds of app't R. A. α	Seconds of chron. corr'n. $\triangle$ T	Diff. Δ	Equat'l diff. $p \Delta$
CLAMP EAST.	*h. m. s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*	*s.*
966 Groombridge	5 22 58.77	....	− .04	− .12	− .38	− .07	− .24	57.92	56.62	1.30	− .05	.00
δ Orionis.....	5 25 41.20	− 4.77	− .04	− .05	− .10	− .02	+ .03	36.25	34.83	1.42	+ .07	+ .07
α Leporis	27 12.67	....	− .04	− .04	− .10	− .02	+ .06	12.53	11.23	1.30	− .05	− .05
ε Orionis......	29 51.34	....	− .03	− .05	− .10	− .02	+ .04	51.18	49.85	1.33	− .02	− .02
CLAMP WEST.												
α Orionis......	48 23.59	− 0.55	− .01	− .13	+ .10	− .02	+ .10	23.08	21.65	1.43	+ .08	+ .08
22 Camelopard	6 05 01.91	....	+ .01	− .24	+ .28	− .05	− .69	01.22	59.84	1.38	+ .03	+ .01
μ Geminorum	15 22.23	....	+ .02	− .13	+ .11	− .02	+ .01	22.22	20.94	1.28	− .07	− .06
γ Geminorum	30 27.89	....	+ .04	− .11	+ .10	− .02	+ .05	27.95	26.63	1.32	− .03	− .03

DECEMBER 31, 1873. $r = -0^s.02$. $c = +0^s.01$ W. $T_0 = 3^h\ 35^m$ chronometer. $\triangle T = -1^h\ 00^m\ 27^s$.

CLAMP WEST.												
θ¹ Ceti.........	2 18 11.08	....	+ .03	− .06	+ .01	− .02	− .03	11.01	43.21	27.80	+ .02	+ .02
38 Cassiopeæ...	22 19.58	....	+ .02	− .12	+ .03	− .05	+ .11	19.57	51.80	27.77	− .01	.00
η Piscium.....	25 11.85	....	+ .02	− .06	+ .01	− .02	− .01	11.79	44.08	27.71	− .07	− .07
ο Piscium....	39 12.07	....	+ .02	− .10	+ .01	− .02	− .02	11.96	44.15	27.81	+ .03	+ .03
β Arietis......	48 08.36	....	+ .02	− .10	+ .01	− .02	− .00	08.27	40.54	27.73	− .05	− .05
50 Cassiopeæ...	53 10.05	....	+ .02	− .26	+ .04	− .06	+ .13	09.91	42.07	27.84	+ .06	+ .01
α Arietis......	3 00 31.90	....	+ .01	− .11	+ .01	− .02	+ .00	31.79	04.07	27.72	− .06	− .05
ξ¹ Ceti	06 47.17	....	+ .01	− .11	+ .01	− .02	− .02	47.04	19.16	27.88	+ .10	+ .10
CLAMP EAST.												
ι Cassiopeæ...	19 10.18	....	+ .01	− .21	− .03	− .05	+ .06	09.96	42.12	27.84	+ .06	+ .02
γ Ceti.........	37 14.23	....	.00	− .10	− .01	− .02	− .01	14.09	46.38	27.71	− .07	− .07
α Ceti.........	56 09.71	....	− .01	− .14	− .01	− .02	− .01	09.52	41.75	27.77	− .01	− .01
48 Cephei......	4 04 53.41	....	− .01	− .40	− .04	− .09	+ .14	53.01	25.40	27.61	− .17	− .02
ζ Arietis......	08 07.68	....	− .01	− .17	− .01	− .02	+ .00	07.47	39.70	27.77	− .01	− .01
α Persei.......	15 48.26	....	− .01	− .22	− .02	− .03	+ .02	47.99	20.20	27.79	+ .01	+ .01
η Tauri	40 27.97	....	− .02	− .17	− .01	− .02	+ .00	27.75	59.99	27.76	− .02	− .02
ζ Persei..	46 21.27	....	− .02	− .22	− .01	− .02	+ .00	41.00	13.11	27.89	+ .11	+ .09
γ¹ Eridani.....	52 37.64	....	− .03	− .14	− .01	− .02	− .02	37.42	09.61	27.81	+ .03	+ .03

DECEMBER 31, 1873. $r = -0^s.02$. $c = +0^s.01$ W. $T_0 = 7^h\ 05^m$ chronometer. $\triangle T = -1^h\ 00^m\ 28^s$.

CLAMP EAST.												
α Leporis.....	6 27 39.49	....	+ .01	− .21	− .01	− .02	− .12	39.14	11.23	27.91	− .01	− .01
ε Orionis......	30 18.13	....	+ .01	− .23	− .01	− .02	− .07	17.81	49.85	27.96	+ .04	+ .04
α Orionis.. ...	48 49.91	....	.00	− .23	− .01	− .02	− .05	49.60	21.66	27.94	+ .02	+ .02
μ Geminorum	7 15 49.13	....	.00	− .29	− .01	− .02	− .01	48.80	20.94	27.86	− .06	− .05
γ Geminorum	30 54.88	....	− .01	− .28	− .01	− .02	− .02	54.54	26.64	27.90	− .02	− .02
51 Cephei.....	41 35.65	....	− .01	− 2.56	− .21	− .49	+ 3.02	35.49	07.36	28.13	+ .21	.00

Reduction of transits of stars for chronometer-correction—Continued.

JANUARY 9, 1874. $r = -0^s.01$. $c = -0^s.01$ W. $T_0 = 4^h\ 15^m$ chronometer. $\Delta T = -1^h\ 00^m\ 33^s$.

Star.	Chron. time over mean of lines.	Red. to mean of lines.	Rate corr'n.	Level corr'n. b B	Coll'n corr'n. c C	Diur'l aberr'n.	Azim. corr'n. a A	Seconds of obs'd transit.	Seconds of app't R. A. a	Seconds of chron. corr'n. Δ T	Diff. Δ	Equat'l diff. $p\Delta$
CLAMP EAST.	h. m. s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
β Arietis......	2 48 12.81	....	+ .01	+ .30	+ .01	− .02	+ .02	13.13	40.44	32.69	.00	.00
50 Cassiopeæ...	53 14.29	....	+ .01	+ .65	+ .03	− .06	− .70	14.22	41.59	32.63	− .06	− .01
ε Arietis......	3 00 36.21	....	+ .01	+ .33	+ .01	− .02	+ .01	36.55	03.97	32.58	− .11	− .10
ξ¹ Ceti........	06 51.39	....	+ .01	+ .25	+ .01	− .02	+ .08	51.72	19.07	32.65	− .04	− .04
ι Cassiopeæ...	19 14.76	....	+ .01	+ .37	+ .03	− .05	− .51	14.61	41.81	32.80	+ .11	+ .03
γ Ceti.........	37 18.75	....	+ .01	+ .12	+ .01	− .02	+ .11	18.98	46.30	32.68	− .01	− .01
α Ceti.........	56 14.27	....	.00	+ .12	+ .01	− .02	+ .11	14.49	41.68	32.81	+ .12	+ .12
CLAMP WEST.												
48 Cephei......	4 04 58.31	....	.00	+ .24	− .05	− .09	− 1.01	57.40	24.84	32.56	− .13	− .01
ζ Arietis......	08 12.21	....	.00	+ .10	− .01	− .02	+ .02	12.30	39.63	32.67	− .02	− .02
α Persei.......	15 52.87	....	.00	+ .13	− .02	− .03	− .18	52.77	20.08	32.69	.00	.00
δ Persei.......	34 30.53	....	.00	+ .09	− .01	− .03	− .16	30.42	57.64	32.78	+ .09	+ .05
η Tauri.......	40 32.46	....	.00	+ .07	− .01	− .02	+ .01	32.51	59.94	32.57	− .12	− .11
ζ Persei.......	46 45.83	....	− .01	+ .01	− .01	− .02	− .04	45.76	13.05	32.71	+ .02	+ .02
γ¹ Eridani.....	52 42.19	....	− .01	.00	− .01	− .02	+ .18	42.33	09.55	32.78	+ .09	+ .09
γ Tauri.......	5 13 10.44	....	− .01	− .01	− .01	− .02	+ .05	10.44	37.79	32.65	− .04	− .04
α Tauri.......	29 14.57	....	− .01	− .02	− .01	− .02	+ .04	14.55	41.91	32.64	− .05	− .05
9 Camelopard.	42 06.69	....	− .01	− .02	− .02	− .05	− .46	06.13	33.34	32.79	+ .10	+ .03

JANUARY 10, 1874. $r = -0^s.02$. $c = -0^s.01$ W. $T_0 = 5^h\ 12^m$ chronometer. $\Delta T = -1^h\ 00^m\ 33^s$.

Star.	Chron. time over mean of lines.	Red. to mean of lines.	Rate corr'n.	Level corr'n. b B	Coll'n corr'n. c C	Diur'l aberr'n.	Azim. corr'n. a A	Seconds of obs'd transit.	Seconds of app't R. A. a	Seconds of chron. corr'n. Δ T	Diff. Δ	Equat'l diff. $p\Delta$
CLAMP WEST.												
ι Cassiopeæ...	3 19 16.15	....	+ .04	− .40	− .03	− .05	− .66	15.05	41.77	33.28	+ .02	+ .01
γ Ceti........	37 19.57	....	+ .03	− .15	− .01	− .02	+ .14	19.56	46.29	33.27	+ .01	+ .01
α Ceti.........	56 14.92	....	+ .03	− .15	− .01	− .02	+ .14	14.91	41.67	33.24	− .02	− .02
48 Cephei......	4 05 00.13	....	+ .02	− .60	− .05	− .09	− 1.39	58.02	24.77	33.25	− .01	− .00
ζ Arietis......	08 23.23	− 10.28	+ .02	− .20	− .01	− .02	+ .03	12.77	39.62	33.15	− .11	− .09
α Persei.......	15 53.83	....	+ .02	− .32	− .02	− .03	− .25	53.23	20.06	33.17	− .09	− .05
δ Persei.......	34 31.62	....	+ .01	− .32	− .01	− .03	− .22	31.05	57.03	33.42	+ .16	+ .10
η Tauri.......	40 41.39	− 7.97	+ .01	− .25	− .01	− .02	+ .01	33.16	59.93	32.23	− .03	− .02
ζ Persei.....	46 46.67	....	+ .01	− .27	− .01	− .02	− .05	46.33	13.04	33.29	+ .03	+ .02
γ¹ Eridani....	52 42.82	....	.00	− .18	− .01	− .02	+ .25	42.86	09.54	33.32	+ .06	+ .06
CLAMP EAST.												
γ Tauri......	5 13 18.73	− 7.60	.00	− .26	+ .01	− .02	+ .06	10.92	37.78	33.14	− .12	− .12
ε Tauri......	21 49.30	....	.00	− .25	+ .01	− .02	+ .03	49.16	15.98	33.18	− .08	− .08
α Tauri......	29 15.37	....	.00	− .25	+ .01	− .02	+ .05	15.16	41.91	33.25	− .01	− .01
9 Camelopard	42 07.66	....	− .01	− .49	+ .02	− .05	− .58	06.55	33.32	33.23	− .03	− .01
ι Aurigæ.....	49 21.54	....	− .01	− .31	+ .01	− .02	− .06	21.15	47.87	33.28	+ .02	+ .02
11 Orionis.....	57 56.13	....	− .01	− .26	+ .01	− .02	+ .06	55.91	22.71	33.20	− .06	− .06
β Orionis.....	6 09 02.95	....	− .02	− .22	+ .01	− .02	+ .19	02.89	29.64	33.25	− .01	− .01
β Tauri.......	18 54.04	....	− .02	− .30	+ .01	− .02	− .03	53.68	20.27	33.41	+ .15	+ .13
δ Orionis.....	26 08.30	....	− .02	− .23	+ .01	− .02	+ .15	08.19	34.85	33.34	+ .08	+ .08
α Leporis....	27 44.46	....	− .02	− .18	+ .01	− .02	+ .26	44.51	11.24	33.27	+ .01	+ .01
ε Orionis.....	29 23.32	....	− .02	− .22	+ .01	− .02	+ .15	23.22	49.88	33.34	+ .08	+ .08
α Columbæ....	35 39.39	....	− .03	− .16	+ .01	− .02	+ .36	39.55	06.35	33.20	− .06	− .05
α Orionis.....	48 55.17	....	− .03	− .26	+ .01	− .02	+ .11	54.98	21.71	33.27	+ .01	+ .01
22 Camelopard	7 05 34.53	....	− .04	− .63	+ .03	− .05	− .71	33.13	59.94	33.19	− .07	− .01

Reduction of transits of stars for chronometer-correction—Continued.

JANUARY 11, 1874. $r = -0^s.02$. $c = +0^s.05$ W. $T_0 = 5^h\ 16^m$ chronometer. $\Delta T = -1^h\ 00^m\ 33^s$.

Star.	Chron. time over mean of lines.	Red. to mean of lines.	Rate corr'n.	Level corr'n. bB	Coll'n. corr'n. cC	Diur'l. aberr'n.	Azim. corr'n. aA	Seconds of obs'd transit.	Seconds of app't R. A. α	Seconds of chron. corr'n. ΔT.	Diff. Δ	Equat'l diff. $p\Delta$
CLAMP WEST.	h. m. s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
ε Arietis	3 00 37.78	....	+ .05	− .43	+ .05	− .02	.00	37.43	03.95	33.48	− .15	− .13
ξ¹ Ceti	06 53.05	....	+ .04	− .41	+ .05	− .02	+ .04	52.75	19.05	33.70	+ .07	+ .07
ι Cassiopeæ	19 20.36	− 3.85	+ .04	− .83	+ .13	− .05	− .28	15.52	41.73	33.79	+ .16	+ .05
γ Ceti	37 20.37	....	+ .03	− .46	+ .05	− .02	+ .06	20.03	46.28	33.75	+ .12	+ .12
α Ceti	56 15.70	....	+ .03	− .51	+ .05	− .02	+ .06	15.31	41.66	33.65	+ .02	+ .02
48 Cephei	4 05 00.31	....	+ .02	− 1.56	+ .23	− .09	− .58	58.33	24.70	33.63	.00	.00
ζ Arietis	08 13.73	....	+ .02	− .63	+ .05	− .02	+ .01	13.16	39.61	33.55	− .08	− .07
α Persei	15 54.46	....	+ .02	− .86	+ .08	− .03	− .10	53.57	20.04	33.53	− .10	− .06
CLAMP EAST.												
δ Persei	34 32.24	....	+ .01	− .83	− .07	− .03	− .06	31.26	57.62	33.64	+ .01	+ .01
η Tauri	40 34.14	....	+ .01	− .64	− .05	− .02	.00	33.44	50.92	33.52	− .11	− .10
ζ Persei	46 47.47	....	+ .01	− .63	− .06	− .02	− .01	46.76	13.03	33.73	+ .10	+ .08
γ¹ Eridani	52 43.58	....	+ .01	− .47	− .05	− .02	+ .06	43.11	09.53	33.58	− .05	− .05
γ Tauri	5 13 12.03	....	.00	− .57	− .05	− .02	+ .02	11.41	37.77	33.64	+ .01	+ .01
ε Tauri	21 50.20	....	.00	− .59	− .05	− .02	+ .01	49.55	15.97	33.58	− .05	− .05
9 Camelopard.	42 08.29	....	− .01	− 1.10	− .12	− .05	− .17	06.84	33.30	33.54	− .09	− .03
ι Aurigæ	49 22.41	....	− .01	− .72	− .06	− .02	− .02	21.58	47.87	33.71	+ .08	+ .06
11 Orionis	57 56.97	....	− .01	− .61	− .05	− .02	+ .02	56.32	22.71	33.61	− .02	− .02
β Orionis	6 09 03.87	....	− .02	− .53	− .05	− .02	+ .06	03.31	29.64	33.67	+ .04	+ .04
β Tauri	18 54.79	....	− .02	− .71	− .06	− .02	− .01	53.97	20.27	33.70	+ .07	+ .06
δ Orionis	26 09.08	....	− .02	− .57	− .05	− .02	+ .04	08.46	34.85	33.61	− .02	− .02
α Leporis	27 45.36	....	− .02	− .48	− .05	− .02	+ .07	44.86	11.24	33.62	− .01	− .04
ε Orionis	30 24.13	....	− .02	− .57	− .05	− .02	+ .05	23.52	49.88	33.64	+ .01	+ .01
ε Columbæ	35 40.36	....	− .02	− .40	− .06	− .02	+ .11	39.97	06.34	33.63	.00	.00
CLAMP WEST.												
α Orionis	48 56.04	....	− .03	− .67	+ .05	− .02	+ .04	55.41	21.72	33.69	+ .06	+ .06
22 Camelopard.	7 05 35.25	....	− .04	− 1.41	+ .13	− .05	− .29	33.59	59.95	33.64	+ .01	.00
γ Geminorum	31 01.10	....	− .05	− .78	+ .05	− .02	+ .02	00.32	26.75	33.57	− .06	+ .06

Normal equations from which azimuthal deviations and chronometer-corrections were deduced.

1873, December 24.

$$\left\{\begin{array}{rrr} 5.4\ \delta T + & .08\,a = & -2.11 \\ .08 & +2.25 & +\ .10 \end{array}\right.$$

and

$$\left\{\begin{array}{rrr} 3.6\ \delta T + & .31\,a_{,} = & -1.26 \\ .31 & +2.09 & +\ .30 \end{array}\right.$$

$\Delta T = -1^h\ 00^m\ 22^s$

$$\left\{\begin{array}{rl} a = & +\ 0^s.058 \\ \delta T = & -\ \ \ .38 \\ a_{,} = & +\ \ \ .198 \end{array}\right.$$

December 26.

$$\left\{\begin{array}{rrr} 6.2\ \delta T + & .52\,a = & -3.53 \\ .52 & +2.43 & +\ .86 \end{array}\right.$$

and

$$\left\{\begin{array}{rrr} 4.5\ \delta T - & .81\,a_{,} = & -2.99 \\ -\ .81 & +2.90 & +1.42 \end{array}\right.$$

$\Delta T = -1^h\ 00^m\ 27^s$

$$\left\{\begin{array}{rl} a = & +\ 0^s.484 \\ \delta T = & -\ \ \ .61 \\ a_{,} = & +\ \ \ .32 \end{array}\right.$$

December 30.

$$\left\{\begin{array}{rrr} 6.1\ \delta T + & .51\,a = & -3.75 \\ .51 & +2.43 & +\ .25 \end{array}\right.$$

and

$$\left\{\begin{array}{rrr} 7.2\ \delta T - & .26\,a_1 = & -4.74 \\ -\ .26 & +3.33 & +\ .80 \end{array}\right.$$

$\Delta T = -1^s.0$ (chr. 2795)

$$\left\{\begin{array}{rl} a = & +\ 0^s.236 \\ \delta T = & -\ \ \ .64 \\ a_{,} = & +\ \ \ .190 \end{array}\right.$$

Second set for epoch $5^h\ 57^m$ by chronometer.

$$\left\{\begin{array}{rrr} 3.1\ \delta T & +\ 1.27\ a_{,,} = & -\ .97 \\ 1.27 & +\ 1.75 & -\ .30 \end{array}\right.$$

and

$$\left\{\begin{array}{rrr} 3.1\ \delta T & +\ .09\ a_{,,,} = & -\ 1.05 \\ .09 & +\ .91 & +\ .28 \end{array}\right.$$

$\triangle T = -1^s.0$

$$\left\{\begin{array}{rl} a_{,,} = & +\ .08 \\ \delta T = & -\ 1.35 \\ a_{,,,} = & +\ .34 \end{array}\right.$$

Chronometer comparisons as read off from the fillet.

Time by 2795.	$\Delta T_{,}$	Sid. time.	Time by 3477.	ΔT
h. m. s.	*s.*	*h. m. s*	*h. m. s.*	*h. m. s.*
2 22 10	− 1.66	2 22 08.34	3 22 36.12	− 1 00 27.78
5 15 46	− 1.41	5 15 44.59	6 16 12.41	27.82
6 25 46	− 1.31	6 25 44.69	7 26 12.54	27.85

December 31.

$$\left\{\begin{array}{rrr} 6.2\ \delta T & +\ .52\ a = & -\ 4.86 \\ .52 & +\ 2.43 & -\ .54 \end{array}\right.$$

and

$$\left\{\begin{array}{rrr} 6.6\ \delta T & +\ .08\ a_{,} = & -\ 5.15 \\ .08 & +\ 3.13 & -\ .18 \end{array}\right.$$

$\triangle T = -1^h\ 00^m\ 27^s$

$$\left\{\begin{array}{rl} a = & -\ 0^s.055 \\ \delta T = & -\ .78 \\ a_{,} = & -\ .038 \end{array}\right.$$

Second set for epoch $7^h\ 05^m$.

$\triangle T = -1^h\ 00^m\ 28^s$

$$\begin{array}{rrr} 4.905\ \delta T & +\ 1.55\ a_{,,} = & +\ .16 \\ 1.55 & +\ 2.50 & -\ .28 \end{array}$$

$$\left\{\begin{array}{rl} a_{,,} = & -\ 0^s.164 \\ \delta T = & +\ .08 \end{array}\right.$$

1874, January 9.

$$\left\{\begin{array}{rrr} 5.3\ \delta T & +\ .13\ a = & +\ 1.69 \\ .13 & +\ 2.34 & +\ .74 \end{array}\right.$$

and

$$\left\{\begin{array}{rrr} 7.2\ \delta T & -\ .65\ a_{,} = & +\ 2.09 \\ -\ .65 & +\ 3.04 & +\ .65 \end{array}\right.$$

$\triangle T = -1^h\ 00^m\ 33^s$

$$\left\{\begin{array}{rl} a = & +\ 0^s.30 \\ \delta T = & +\ .31 \\ a_{,} = & +\ .281 \end{array}\right.$$

January 10.

$$\left\{\begin{array}{rrr} 7.0\ \delta T & -\ .26\ a = & -\ 1.92 \\ -\ .26 & +\ 3.33 & +\ 1.35 \end{array}\right.$$

and

$$\left\{\begin{array}{rrr} 12.0\ \delta T & +\ 2.73\ a_{,} = & -\ 2.14 \\ 2.73 & +\ 3.84 & +\ .65 \end{array}\right.$$

$\triangle T = -1^h\ 00^m\ 33^s$

$$\left\{\begin{array}{rl} a = & +\ 0^s.385 \\ \delta T = & -\ .26 \\ a_{,} = & +\ .353 \end{array}\right.$$

January 14.

$$\left\{\begin{array}{rrr} 5.8\ \delta T & -\ .16\ a = & -\ 3.68 \\ -\ .16 & +\ 2.78 & +\ .55 \end{array}\right.$$

and

$$\left\{\begin{array}{rrr} 13.1\ \delta T & +\ 2.89\ a_{,} = & -\ 7.95 \\ 2.89 & +\ 3.56 & -\ 1.45 \end{array}\right.$$

$\triangle T = -1^h\ 00^m\ 33^s$

$$\left\{\begin{array}{rl} a = & +\ 0^s.162 \\ \delta T = & -\ .63 \\ a_{,} = & +\ .103 \end{array}\right.$$

Second set.

$$\left\{\begin{array}{rrr} 2.2\ \delta T & +\ .05\ a_{,,} = & -\ 1.39 \\ .05 & +\ .91 & +\ .10 \end{array}\right.$$

$a_{,} = +\ .145$

Synopsis of results for correction and rate of chronometer.

Date.		Epoch T_0.	Chron. Frodsham 3477, correction ΔT_0.		Hourly rate. r.
1873.		*h. m.*	*h. m. s.*	*s.*	*s.*
December	24	3 38 by chron.	− 1 00 22. 38	± 0. 014	− . 200
	26	3 26	27. 61	. 013	− . 002
	30	5 52	27. 82	. 010	− . 040
	31	3 35	27. 78	. 011	− . 040
	31	7 05	27. 92		
1874.					
January	9	4 15	32. 69	. 012	− . 008
	10	5 12	33. 26	. 010	− . 020
	11	5 16	33. 63	. 014	− . 015

About December 24, the chronometer changed its rate rapidly; thus the difference in ΔT_0 for the 22d and 24th is $1\frac{3}{4}$ seconds and for the 24th and 26th $5\frac{1}{4}$ seconds nearly; after this, the rate was tolerably steady.

TELEGRAPHIC CONNECTION AND EXCHANGE OF TIME-SIGNALS.

The line connecting Washington and Key West passed through Augusta, Ga., Lake City, Fla., and Punta Rasa, Fla., at each of which intermediate places there were automatic repeaters. The direct distance between the terminal stations is nearly 1,100 statute miles, and by wire and cable 1,432 miles.* The same circuit was used on every night of exchanges. For transmissions of signals, the Washington clock was made to break the circuit every second for about five minutes; the Key West chronometer caused the circuit to be broken every second (and another chronometer every other second) for about three minutes. There were also transmitted arbitrary signals from both ends. The following scheme exhibits the times (first and last minute breaks) of exchanges:

Date.	Washington, D. C. Clock-signals sent to Key West.	Key West, Fla. Chronometer-signals sent to Washington.
Dec. 24	From 4^h 19^m to 4^h 23^m sid. time	From 5^h 09^m to 5^h 13^m and from 5^h 18^m to 5^h 21^m chr.† time.
26	From 4^h 44^m to 4^h 49^m	From 5^h 34^m to 5^h 39^m.
30	From 5^h 11^m to 5^h 16^m	From 6^h 05^m to 6^h 08^m. [Signals by 2d chr. rejected.]
31	From 5^h 00^m to 5^h 05^m	Twenty-five arbitrary signals between 6^h 18^m and 6^h 21^m.
Jan. 9	At 6^h 09^m and 6^h 49^m: also two sets† of arbitrary signals	From 6^h 39^m to 6^h 42^m.
10	From 6^h 29^m to 6^h 33^m	From 7^h 27^m to 7^h 30^m.
11	From 7^h 02^m to 7^h 05^m	From 7^h 37^m to 7^h 40^m.

*According to information kindly furnished (July 27, 1876) by the manager of the Western Union Telegraph Office in Washington, the lengths of lines between the connected stations are as follows:

	Statute miles.
Washington to Richmond	116
Richmond to Augusta, via Goldsboro'	478
Augusta to Savannah	132
Savannah to Lake City	202
Lake City to Punta Rasa	366
	1294
Cable, Punta Rasa to Key West, 120 knots	138
Total length	1432

† First set not used or reported.

For the determination of the difference of longitude, we have the following simple formulæ: Let

$\varDelta\lambda$ = difference of longitude, west longitude being reckoned positive;

t_e and $\varDelta t_e$ = the clock-time and the clock-correction at the *eastern* station when sending a signal;

t_w and $\varDelta t_w$ = the clock-time and the clock-correction at the *western* station when *receiving* the signal;

t_w' and $\varDelta t_w'$ = the clock-time and the clock-correction at the *western* station when *sending* a signal;

t_e' and $\varDelta t_e'$ = the clock-time and the clock-correction at the *eastern* station when *receiving* the signal;

x = transmission time of electric impulse inclusive of all causes of delay:

then, supposing the clock-times corrected for personal equations, and the transmission time between the two stations the same either way, we have from the eastern signals

$$\varDelta\lambda - x = t_e + \varDelta t_e - (t_w + \varDelta t_w) = \lambda_e$$

and from the western signals

$$\varDelta\lambda + x = t_e' + \varDelta t_e' - (t_w' + \varDelta t_w') = \lambda_w$$

also,

$$\varDelta\lambda = \tfrac{1}{2}(\lambda_e + \lambda_w) \text{ and } x = \tfrac{1}{2}(\lambda_w - \lambda_e)$$

Telegraphic difference of longitude between Washington and Key West, 1873–1874.

I.—FROM WASHINGTON OR EASTERN SIGNALS.

Date.	Transmitted from Washington. Clock-time.	Correction to clock.	Washington sid. time.	Received at Key West. Chronometer-time.	Correction to chronometer.	Key West sid. time.	$\lambda_e = \Delta\lambda - x$
1873–'74.	h. m. s.	s.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	m. s.
Dec. 24	4 19 01	+ 6.45	4 19 07.45	5 00 28.89	− 1 00 22.65	4 00 06.24	19 01.21
26	4 43 59	5.83	4 44 04.83	5 25 31.26	27.62	4 25 03.64	.19
30	5 15 50	4.63	5 15 54.63	5 57 21.27	27.82	4 56 53.45	.18
31	5 59 55	4.70	5 59 59.70	5 41 26.33	27.86	4 40 58.47	.23
*Jan. 9	6 09 31	5.60	6 09 36.60	6 51 07.91	32.71	5 50 35.20	.40
10	6 32 31	5.56	6 32 36.56	7 14 08.51	33.30	6 13 35.21	.35
11	7 03 26	5.94	7 03 31.94	7 45 04.25	− 1 00 33.67	6 44 30.58	.36

* A set of arbitrary signals gave precisely the same result, viz: 19m 01s.40.

II.—FROM KEY WEST OR WESTERN SIGNALS.

Date.	Transmitted from Key West. Chronometer-time.	Correction to chronometer.	Key West sid. time.	Received at Washington. Clock-time.	Correction to clock.	Washington sid. time.	$\lambda_w = \Delta\lambda + x$
1873–'74.	h. m. s.	h. m. s.	h. m. s.	h. m. s.	s.	h. m. s.	m. s.
Dec. 24	5 19 28	− 1 00 22.72	4 19 05.28	4 38 00.48	+ 6.42	4 38 06.90	19 01.62
26	5 36 32	27.62	4 36 04.38	4 55 00.10	5.82	4 55 05.92	01.54
30	6 07 31	27.82	5 07 03.18	5 26 00.13	4.63	5 26 04.76	01.58
*31	6 19 23.46	27.89	5 18 55.57	5 37 52.56	4.69	5 37 57.25	01.68
Jan. 9	6 40 37	32.71	5 40 04.29	5 59 00.48	5.61	5 59 06.09	01.80
10	7 27 38	33.30	6 27 04.70	6 46 00.88	5.57	6 46 06.45	01.75
11	7 37 38	− 1 00 33.66	6 37 04.34	6 56 00.15	5.97	6 56 06.12	01.78

* From a set of twenty-five arbitrary signals.

To obtain some tolerable approximation for probable error and weight to each of the seven values for difference of longitude, there were combined for each night the probable errors of the clock-correction, of the chronometer-correction, and of the personal equation, the resulting value $\varepsilon = \sqrt{\varepsilon_{/}^2 + \varepsilon_{//}^2 + \varepsilon_{///}^2}$ was taken to answer to λ_e λ_w and $\varDelta\lambda$; the weight given equal $\frac{1}{\varepsilon^2}$.

Results for difference of longitude, Washington and Key West, with approximate probable errors and relative weights; also wave and armature time.

Date.	$\Delta\lambda = \frac{1}{2}(\lambda_e + \lambda_w)$	ϵ.	Relative weight.	x.
1873–'74.	m. s.	s.		s.
December 24	19 01.42	± 0.044	518	0.20
26	01.37	.037	731	0.18
30	01.38	.036	773	0.20
31	01.45	.036	773	0.22
January 9	01.60	.046	472	0.20
10	01.55	.045	494	0.20
11	01.57	.047	453	0.21

Indiscriminate mean of values of $\Delta\lambda$ .... $19^m\ 01^s.48 \pm 0^s.024$

Weighted mean $\frac{\Sigma_w \cdot \Delta\lambda}{\Sigma_w}$ .... $19\ 01.461 \pm 0.015$

Mean of first 4 nights, circle at Washington E .... 19 01 .40 } 19 01 .485
Mean of last 3 nights, circle at Washington W........ 19 01 .57 }

This last combination would free the result from any possible residual error in the assigned collimation constants for the transit-circle in the two years, and, by applying the weights given, we shall produce the most probable value for our final difference of longitude, viz:

$\Delta\lambda$ from 4 nights in 1873 .... $19^m\ 01^s.404 \pm 0^s.019$
$\Delta\lambda$ from 3 nights in 1874 .... $19\ 01.573 \pm 0.027$

Mean $\Delta\lambda$ .... $19\ 01.488 \pm 0.0165$

The wave and armature time is given in the column headed x; the separate values are sufficiently accordant, and, comparing the mean with the greater value found by Professor Harkness in the telegraphic determination of the difference of longitude between Washington and Havana in 1868 (see Appendix I, Washington Astronomical Observations of 1867, printed in 1870), the difference, $0^s.36 - 0^s.20$, is sufficiently accounted for by the fact that in the Havana line there was one more repeater and about 100 statute miles of additional cable in the circuit. The apparently large value of x in each determination is no doubt due to the resistance offered by the submarine cable, and, unless the electrical resistance was the same at Washington and Key West, the simple mean $\frac{1}{2}(\lambda_e + \lambda_w)$ would not represent the true difference of longitude; the records give no information on this point.

RESULTING LONGITUDE OF KEY WEST AND OF LIGHT-HOUSES IN ITS VICINITY.

According to Coast Survey Report of 1872, p. 234, (printed in 1875), the telegraphic longitude of the dome of the United States Naval Observatory is............................ $5^h\ 08^m\ 12^s.09 \pm 0^s.06$ W. of Gr.
Reduction to transit-circle...... .... $+ 0.066$
Difference of longitude, Washington and Key West....... .. $+ 19\ 01.488 \pm 0.017$

Longitude of Key West astronomical station .... { $5\ 27\ 13.644 \pm 0.062$
{ $81°\ 48'\ 24''.66 \pm 0''.93$

Referring this, by means of triangulation, to Tift's Observatory or Lookout, the longitude of the latter becomes 81° 48′ 27″.86. In the Coast Survey Report for 1851, pp. 164 and 410, the longitude of this station is given as 81° 48′ 30″.73, showing that this old determination, and consequently also the triangulation up to date, was only in error 2″.87, or $0^s.19$, as compared with the present result.

Respecting the older determinations, we may, in the first place, compare the results of the moon-culminations observed in 1849, by Assistant J. E. Hilgard, at Sand Key (0″.02 east of the light), with the telegraphic result for the same, viz: The observer reports in 1851 the result of 18 moon culminations observed in July and August, 1849, from Professor Pendleton's reduction, and corrected for error of Nautical Almanac place, $5^h\ 27^m\ 27^s.1$; Mr. Main deduces, in March, 1857, from 19 moon-culminations, the improved result, $5^h\ 27^m\ 28^s.7 \pm 1^s.2$ (I.), (which includes one case previously rejected). The value resulting from the present investigation is $5^h\ 27^m\ 30^s.68$, indicating

a personal equation of about 0ˢ.07. Secondly, we can compare the chronometric result of 1852 with the telegraphic result. Under date of December 10, 1852, Assistant J. E. Hilgard reports the result of his chronometric determination of the longitude of Key West as follows:

Longitude of Professor Gibbes' observatory, at Charleston, S. C.	$5^h\ 19^m\ 44^s.0$
From transportation of 10 chronometers between Charleston and Key West and return, in February, March, and April, 1852, the difference of longitude	7 29 .65
Hence, longitude of Key West, transit-station of 1852	5 27 13 .65
Geodetic difference, Key West transit of 1852 and Sand Key astronomical station	17 .25
Hence, longitude of Sand Key astronomical station	5 27 30 .90 / 81° 52′ 43″.5 } II.

which is the basis (omitting fraction) of the value given in Coast Survey Report for 1851, p. 164, and which corresponds to the longitude of Key West light, 81° 48′ 07″.13, showing the excess 2″.87, as stated above.

The preference was given to the chronometric result, for the reason that it is less liable to be affected with a constant error than results by moon-culminations; moreover, it lies between the first-named and another previous determination, which earlier result is as follows: From a chronometric determination by Prof. J. H. C. Coffin, U. S. N. (now superintendent of the American Ephemeris), the longitude of the Key West light, depending on the meridians of the Morro Castle, Havana, and the Balize, is stated, in a report by the Bureau of Ordnance and Hydrography, Navy Department, in 1843, to be

	$5^h\ 27^m\ 14^s.0$	or	81° 48′ 30″	and reducing to
Sand Key light	+ 18 .4		4 35 .9	
Sand Key light	5 27 32 .4		81 53 05 .9	III.

In conclusion, I append the geographical positions of the Key West light, the Sand Key light, and the Northwest Channel light,* giving the corrected longitudes, viz:

	Latitude.	Longitude.		
Key West light	24° 32′ 58″.09	81° 48′ 04″.26	or	$5^h\ 27^m\ 12^s.28$
Sand Key light	24 27 10 .00	81 52 40 .15		5 27 30 .68
Northwest Channel light	24 37 04 .05	81 53 57 .97		5 27 35 .86

I remain, sir, yours, most respectfully,

CHAS. A. SCHOTT,
Assistant, Coast Survey.

Hon. CARLILE P. PATTERSON,
Superintendent United States Coast Survey.

* In connection with these lights, the longitude of Morro light, Havana, may be given, based upon the latest telegraphic longitude of the Washington Observatory and the results reported by Professor Harkness in his paper above referred to.

We have, longitude of Washington, dome of Observatory	$5^h\ 08^m\ 12^s.09$
Difference of longitude, Washington and Morro light	0 21 13 .43
Longitude of Morro light	5 29 25 .52
	or 82° 21′ 22″.80

with an unknown correction for personal equation.

It will be interesting to compare this with the result deduced from observations made early this century, at Havana, by Don J. J. de Ferrer. The meridian of Havana was then the best astronomically-determined meridian in the Gulf of Mexico. Don Ferrer's elaborate paper is contained in volume IV of the Memoirs of the Astronomical Society of London, 1830, No. XXXI, p. 569 *et seq.* From 20 observed occulations, between 1808 and 1812, he gives finally—

Havana, Don Antonio Robredo's observatory	$5^h\ 38^m\ 47^s.7$	W. of Paris.
Difference of longitude, Paris and Greenwich	9 21 .1	
Longitude of Havana observatory	5 29 26 .6	W. of Greenwich.
Reduction to Great Tower of Morro	1 .6	
Longitude of the Tower of Morro, (probably very near the light)	5 29 28 .2	

a result probably correct within the limit of 3ˢ.

ADDITIONAL NOTE.—In a letter dated June 23, 1877, Capt. F. W. Green, U. S. N., communicated to me the result of his new determination of Lieutenant Puyazon's pier of 1868, as connected with the Coast Survey station at Key West. It differs 0ˢ.42 from Professor Harkness's result, and the difference is no doubt due to the fact that the chronometer had to be carried, in 1868, some distance between the observing and the telegraph stations. This new determination, of November, 1875, gives the longitude of the Morro light $5^h\ 29^m\ 25^s.94$ W. of Greenwich.

APPENDIX No. 10.

REPORT ON MOUNT SAINT ELIAS, MOUNT FAIRWEATHER, AND SOME OF THE ADJACENT MOUNTAINS BY WILLIAM H. DALL, ACTING ASSISTANT IN THE UNITED STATES COAST SURVEY.

I.—HISTORICAL NOTES.

On the 20th of July, 1741 (old style), Bering and his associates made the continental shore of Northwest America, and, in what they estimated as latitude 59° 15′ and longitude 124° 40′ west from Ferro, they saw a great mountain, and under it a point, which they named after Saint Elias, the patron saint of the day. It is probable that they saw about the same time all the other high peaks of the adjacent region, though the fact is not mentioned in the imperfect records existing of this expedition.

On the 3d of May, 1778, Capt. James Cook, in search of a northeast passage, saw a beautiful peak, which he named Mount Fairweather, and which he placed in latitude 58° 52′ north and longitude 138° west from Greenwich. The next day, he raised a great peak to the northward, and, believing it to be that seen by Bering, he placed it on his chart as Mount Saint Elias, in latitude 60° 27′ and longitude 141° west.

Considering the great advance in nautical instruments and tables since the days of Cook, these results are extremely creditable. Cook did not attempt to measure the heights of either of these mountains, as far as we can learn from the authorized edition of his voyage.

In 1786, the celebrated La Pérouse saw Saint Elias on the 23d of June, and his astronomer, d'Agelet, essayed to measure it with sextant angles from the vessel. The height resulting from his observations was 1,890 toises, or about 12,600 feet. As the latitude assigned for the vessel's position, however, was indubitably ten or twelve miles in error, no weight can be assigned to his result. His assumed base-line was hardly less than fifteen miles too short.

Shortly afterward, he saw Mount Fairweather, and another high mountain, which he named Mount Crillon, after the French minister of marine; but it does not appear from his narrative that the height of either was determined by his party. The positions he assigned to them are, nevertheless, quite near to the latest determinations.

In 1787, Douglas saw Mount Saint Elias, on the 2d of August; and in this year the first Russian explorations of this part of the coast were made by Bechareff and Ismyloff. They are not recorded as passing to the south of Lituya Bay, where they had already been preceded by La Pérouse. About this time, numerous English and American trading-vessels were fitted out for commercial operations in this region. Though much incidental geographical information was thus obtained, I have discovered nothing of importance relative to the present subject.

On the 19th of June, 1791, Señor Don Alessandro Malespina saw Saint Elias, and attempted from on shipboard to measure its height. He found it to be 17,851 feet, which in the round numbers of 17,800 and 17,860 feet has been adopted on many charts, and is nearer the truth than the estimates of any other navigator which have been published. For Fairweather he obtained a height of 14,695 feet, which is also not very far from the truth.

On the 28th of June, 1794, Vancouver saw Saint Elias, and gives in his voyage the first view of it which was ever published. This was taken from the vicinity of Icy Bay, and bears some resemblance to the mountain, though much seems in the plate to have been sacrificed to artistic effect. Vancouver placed the peak in latitude 60° 22′.5 and longitude 140° 39′ west, being very near the recent determinations in latitude, but too far to the eastward. The same may be said of his position for Mount Fairweather, which he located July 25, 1794, in latitude 58° 57′ and longitude 137° 13′ west. He appears to have made no attempt to measure the elevation of either peak.

Sir Edward (now Admiral) Belcher, in 1837, was the next navigator of importance to visit this region, and from his narrative it would seem that he placed special importance on the determination of the position and height of Saint Elias. He failed, however, to get observations of precision from on shore at Point Rion, as he had intended; and that his results were satisfactory we may doubt, as he does not give any elevation or position for the mountain in his narrative, and even omits it entirely from his chart. This, notwithstanding his mention of having obtained satisfactory observations. Whatever the results may have been, most unfortunately they do not appear to have been made public under his name, except a view which he gives of the mountain, which is hardly more satisfactory than that of Vancouver.

Tebenkoff visited this region in 1847, and from his hydrographic notes we learn that he placed the peak in latitude 60° 22′.6 and longitude 140° 54′ west, with a height of 17,000 feet. He mentions that Vasilieff from his vessel determined the height of Mount Fairweather as 13,946 feet, and placed it in latitude 58° 57′ and longitude 137° 27′ west.

Since that time the coast has been annually visited by whalers and traders; but their observations, if any, have not been made public; and it has been reserved for the Coast Survey, through one of its parties, to make the latest, and, we have reason to believe, the most precise contribution to our knowledge of the subject.

The United States Coast Survey schooner Yukon, under my charge, with Mr. Marcus Baker as astronomical observer, left Sitka on the 11th of May, 1874. We rated our eight chronometers on the 5th by means of very satisfactory observations of equal a. m. and p. m. altitudes of the sun. On the 13th, we obtained forenoon sextant-altitudes from a sea-position on Mounts Fairweather and Crillon; similar observations in the afternoon and on the following day. On the 15th we entered Lituya Bay, where we remained until the morning of the 19th. Here an astronomical position and azimuth were well determined on shore with the sextant, vertical circle, and theodolite, and connected with a triangulation including Mounts Fairweather and Crillon. Vertical angles for the altitude of these mountains were obtained with the theodolite.

On leaving Lituya Bay, while becalmed in its immediate vicinity, and with our position well fixed by bearings on known points of the shore, additional sextant-altitudes were obtained on Mounts Crillon, Fairweather, and Saint Elias.

On the 20th, in the vicinity of Dry Bay, with a position well fixed by a large series of observations for time and latitude, additional observations with the sextant were obtained on Mount Saint Elias.

On the 21st, we entered Port Mulgrave.

On the 22d, a series of observations similar to those mentioned at Lituya were obtained, and completed on the 23d, together with the remainder of the triangulation on Mount Fairweather, and a portion of one on Saint Elias. A full and careful series of double-zenith distances, on Mounts Saint Elias, Fairweather and several other mountains, was obtained and connected with the astronomical azimuth line.

On the 24th, additional astronomical observations were made—the 25th being occupied with a reconnaissance survey of the port—and on the 26th we sailed from Port Mulgrave. On our way out, intersections on Mounts Cook and Vancouver were made by compass-bearings, from a position fixed by bearings on the land. At the same time a sketch was obtained of Mount Saint Elias.

On the 27th, from a position at sea determined by sextant-observations for time and latitude, we obtained a series of sextant-altitudes on Mount Saint Elias; and an azimuth was observed directly between the mountain and the sun with the same instrument.

On the 7th of June we were enabled to rate our chronometers again with good success at Saint Paul, Kadiak.

From the material thus obtained, the results, tabulated with previous measurements, below have been arrived at.

Mount Saint Elias.

Date.	Authority.	Height.	Latitude.	Longitude.
		Feet.	° ′ ″	° ′ ″
1786	La Pérouse	12, 672	60 15 00	140 10 00
1791	Malespina	17, 851	?	?
1794	Vancouver	None.	60 22 30	140 39 00 W.
1847	Rus. Hydr. Ch., 1378	17, 854	60 21 00	141 00 00
1847	Tebenkoff (notes)	16, 938	60 22 36	140 54 00
1849	Tebenkoff, Chart VII	16, 938	60 21 30	140 54 00
	Buch. Can. Inseln	16, 758	60 17 30	140 51 00
1872	Eng. Adm. Ch., 2172	14, 970	60 21 00	141 00 00
1874	United States Coast Survey	19, 500 ± 400	60 20 45	141 00 12

Mount Fairweather.

Date.	Authority.	Height.	Latitude.	Longitude.
		Feet.	° ′ ″	° ′ ″
1791	Malespina	14, 589	?	?
1894	Vancouver	None.	58 57 00 N.	137 13 00 W.
1847	Vasilieff	13, 946	?	?
1847	Tebenkoff (Hydr. notes)	14, 000	58 57 00	137 27 00
1848	Rus. Hydr. Ch., 1396	14, 708	58 58 00	137 32 00
1849	Tebenkoff, Ch. No. VII	13, 864	58 57 00	137 27 00
1855	Eng. Adm. Chart	14, 708	58 58 00	137 32 00
1874	United States Coast Survey	15, 500 ± 150	58 54 24	137 30 59

Other mountains.

U. S. C. S.	Name.	Height.	Latitude.	Longitude.
		Feet.	° ′	° ′
1874	Mount Crillon	15, 900 ± 500	58 40	137 02. 7 W.
1874	Mount Cook, approximate	16, 000	60 15	140 00
1874	Mount Vancouver, approximate	13, 100	60 13. 7	139 43
1874	Mount La Pérouse, approximate	11, 300	58 34	136 58

Mount Cook and Mount Vancouver are two high peaks of the Saint Elias Range, to the southward and eastward of Mount Saint Elias; and by the authority of the Superintendent of the United States Coast Survey, as they have been hitherto without distinct appellations, are now named in honor of those distinguished navigators.

In like manner, to a high peak near the sea at Icy Cape, just south and east of Lituya Bay, is now applied the name of La Pérouse. Of this, we were only able approximately to fix the position and height.

GENERAL CONSIDERATIONS.

The elevation heretofore assigned to Mount Saint Elias has varied greatly. When the circumstances under which previous observations have been obtained are considered, this is not surprising. No publication has been made of any angles for elevation taken with any instrument but a sextant. These were almost invariably obtained from on shipboard, with no means of estimating the refraction, and with positions often greatly in error, especially in longitude.

Thus, Tebenkoff gives a height of 16,938 feet; but we know that his position at Port Mulgrave was about six miles in error. La Pérouse, with a position now known to be ten miles in error in latitude alone, obtained 12,672 feet. The Admiralty chart gives the height of 14,970, and others vary between 16,700 and 17,800 feet. Since the data by which all these results were obtained are

inaccessible, and in most cases only the *result* of the original computations was preserved, it is hardly worth while to attempt any further reconciliation of these discrepancies. It is possible, however, that part of them may be due to a hitherto unsuspected cause, namely, that of mistaken identity.

Off shore, Mount Saint Elias is unmistakable. Rising above the fogs, which at some seasons envelop its base, it may be seen when all other land is far below the horizon. But in approaching the coast at Port Mulgrave, it is often lost sight of before its position, relative to the port, can be recognized. This was the case on the occasion of our visit. After being a few hours in port, the fog cleared up considerably, and we saw a very high peak in about the direction in which we supposed Saint Elias to bear. My sailing-master identified it as that mountain, as he had seen it for several weeks on a previous visit. Judge, then, of our surprise when, later, the distant haze disappeared, and the majestic peak of the true Saint Elias became visible. He then declared that during his previous stay at Port Mulgrave, hazy weather prevailing, he had never seen the real mountain at all, and had ascribed the difference in its appearance from that of Saint Elias, as seen from the sea, to his different point of view.

The error might easily occur, as the second mountain (Mount Cook) seems to be upward of 16,000 feet in height. It is also nearer Port Mulgrave, and its position more easterly than that of Mount Saint Elias, as is the position given by some of the authorities for the great peak, to the eastward of its true position. Some details as to the appearance of Mount Saint Elias and Mount Fairweather, and the characteristics of this great uplift, may not be out of place here.

Mount Saint Elias, from the entrance of Yakutat Bay, as represented in the accompanying sketch, (No. 22), rises from a confused mass of broken mountains behind an elevated table-land.*

This plateau is apparently two or three hundred feet in height, and, as mentioned by La Pérouse, in some places the sea breaks against its base, and in others a low and narrow strip of flat beach, formed by streams cutting through the escarpment, intervenes between the cliff and the sea. These flats are green, and often covered with spruce and alders. The top of the table-land appears quite destitute of vegetation, resembling a plowed field, with heaps of bowlders and gravel irregularly distributed upon it. This is probably glacial detritus. The face of the cliff on the northwest shore of the Bay of Yakutat is evidently composed of nearly horizontal stratified rocks. These we supposed to be similar to the horizontal Tertiary strata found at various points near Port Mulgrave, on the opposite side of the bay. Large patches of clean, undisturbed snow lay in various places on the top of the table-land; but we saw nothing resembling a glacier there.

The surface of the plateau rises a little from the edges of the cliffs, and then falls to the axis of a valley parallel with the trend of the mountains, which is interposed between the table-land and the base of the range. In this valley several small glaciers terminate, having their sources on the lower part of the mountain-sides. A considerable stream, the waters of which are probably derived from the melting of the glaciers, falls hence into the bay. At the head of the Bay of Yakutat is a small inlet called Disenchantment Bay, where glaciers come down to the sea, and send their floating fragments, laden with earth and stones, out into the sea. But from the mountains which border on the Bay of Yakutat itself no such ice comes down.

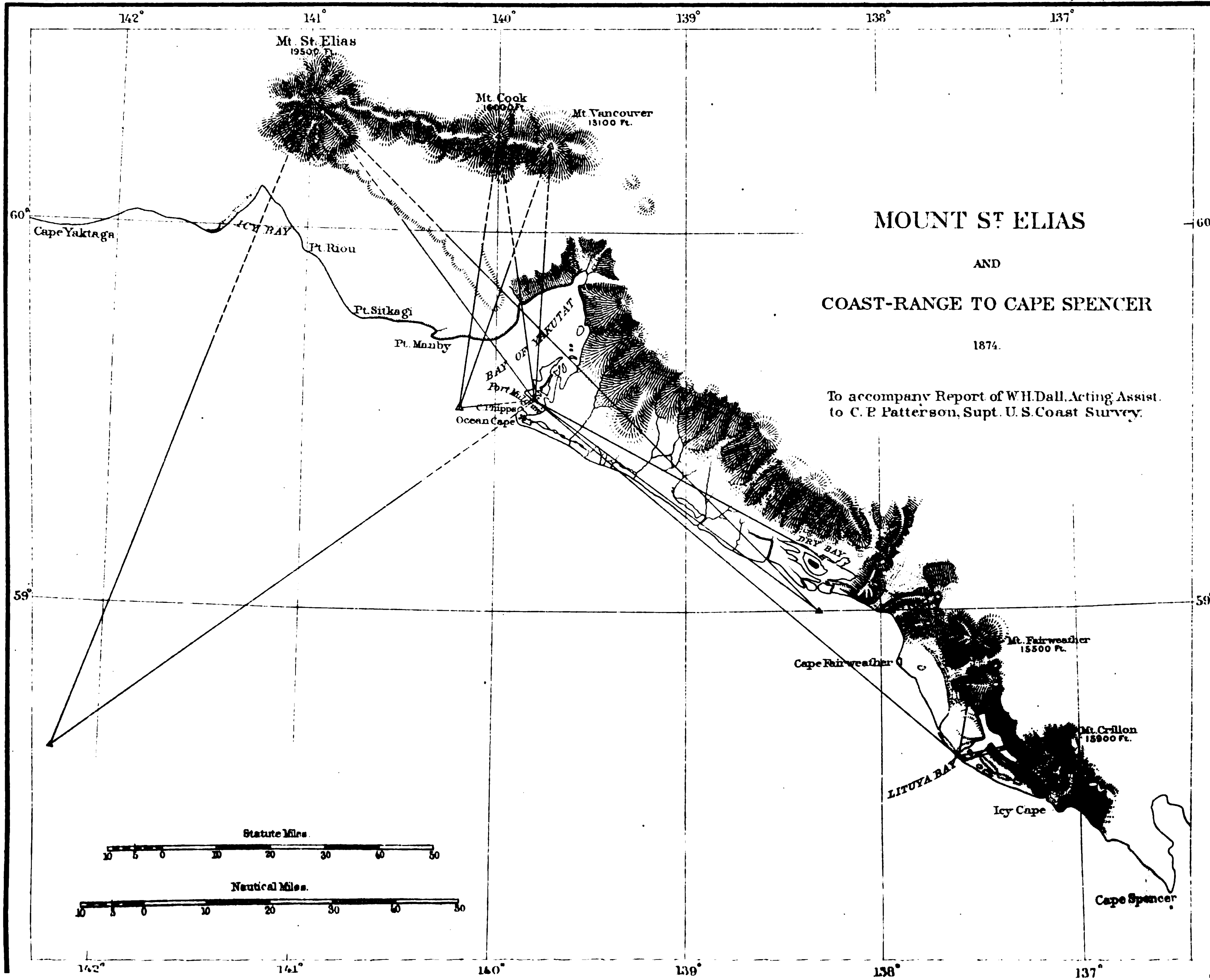
To the east of the peak the range is continuous with Saint Elias, and also apparently to the northwest of it, reaching to at least two-thirds the height of the peak itself.

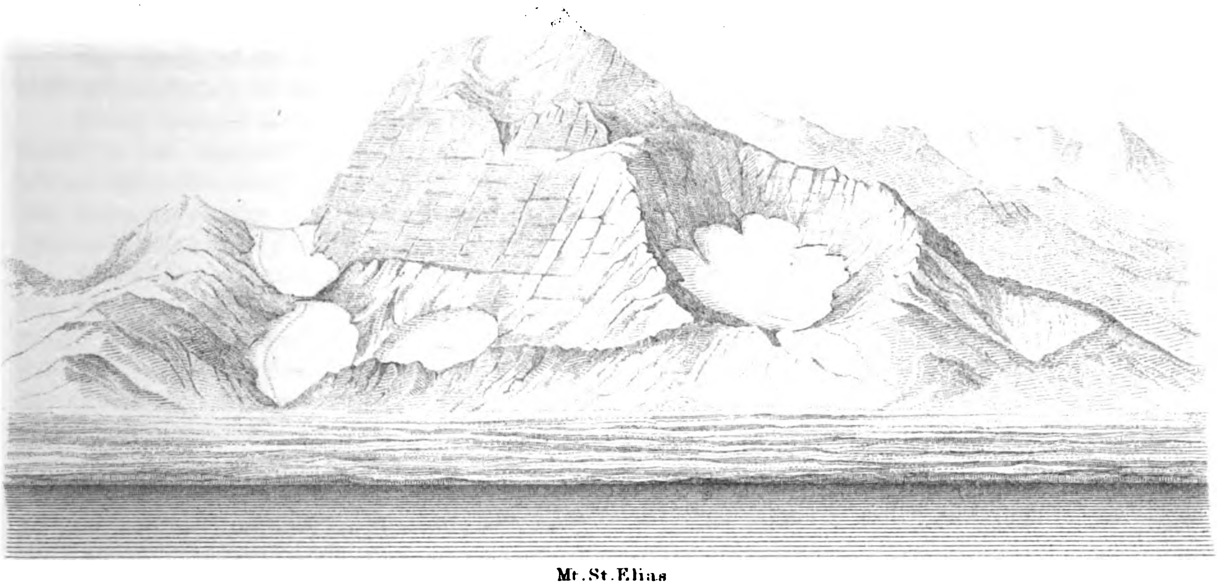
Separated from Elias by a deep trough, in which two large beds of snow and ice lie, one somewhat below the other, and with their axis in a northwesterly direction, some small, rather rounded mountains descend toward the plateau.

Toward the bottom of the east-southeast flank of Saint Elias is a great rocky amphitheater, with high, ragged sides, open to the south and east. In this is a similar snow-bed. These beds, being destitute of lateral or other moraines, and apparently unable to move, from the peculiarities of the topography, we supposed were not true glaciers, and, indeed, from our position we could see nothing on the flanks of the peak which was unmistakably a glacier.

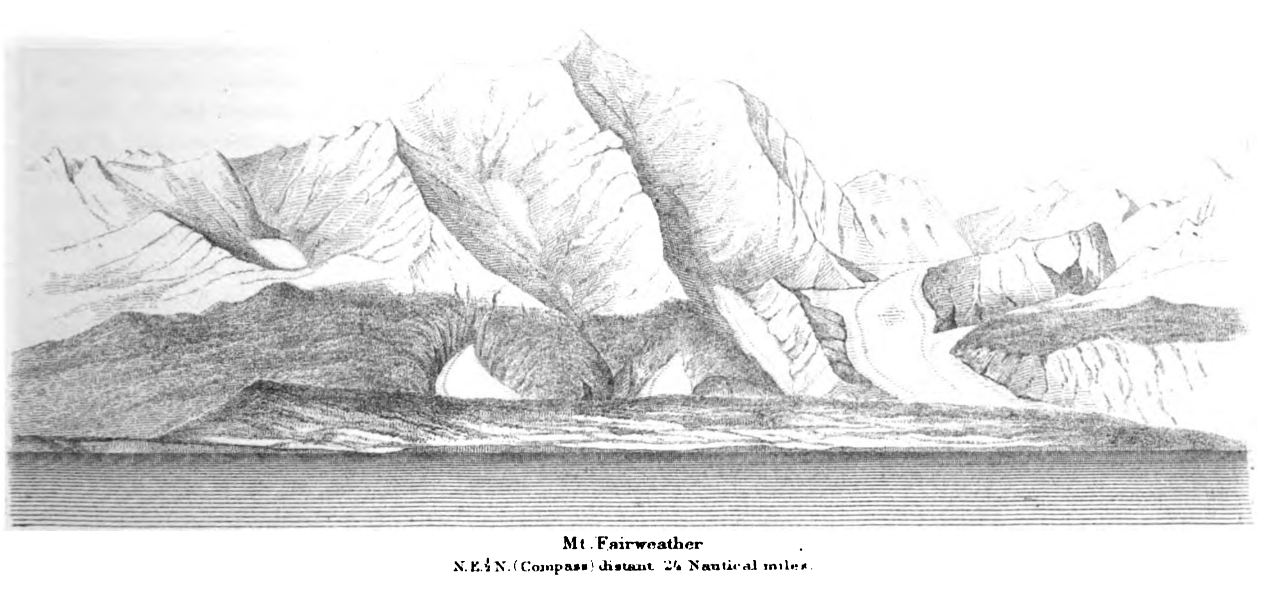
The great amphitheater may be the crater of an extinct volcano; but the fact that bedded strata, without the curves usual in beds of igneous rocks, were plainly visible in the face of its cliffs, and conformable with those on the adjacent rock-face of Elias, rendered this doubtful. The impression it left on our minds was that it was not a crater.

* On the plate the distances are in nautical miles, and the bearings magnetic.


MOUNT S^T ELIAS
AND
COAST-RANGE TO CAPE SPENCER
1874.
To accompany Report of W.H. Dall, Acting Assist. to C. P. Patterson, Supt. U. S. Coast Survey.
Mt. St. Elias
19500 Ft.
Mt. Cook
16000 Ft.
Mt. Vancouver
13100 Ft.
Cape Yaktaga
Pt. Riou
Pt. Sitkagi
Pt. Manby
BAY OF YAKUTAT
Port Mulgrave
C. Phipps
Ocean Cape
DRY BAY
Cape Fairweather
Mt. Fairweather
15500 Ft.
Mt. Crillon
15900 Ft.
LITUYA BAY
Icy Cape
Cape Spencer
142°
141°
140°
139°
138°
137°
60°
59°
Statute Miles
10 5 0 10 20 30 40 50
Nautical Miles.
10 5 0 10 20 30 40 50



Mt. St. Elias
N.W. by W. (Compass) distant 53 Nautical miles



Mt. Fairweather
N.E. ½ N. (Compass) distant 24 Nautical miles.

Pre-eminent in grandeur is the southern face of the mountain. With few and but insignificant foot-hills, it rises abruptly from the valley; and, at about five thousand feet above its base, the entire side of the mountain is formed of an immense rock-face, inclined at an angle of 45° to the sea, rising eight or ten thousand feet without a break in its continuity. It terminates somewhat irregularly above, and the upper contours of the peak remind one of the granite peaks of the Californian Sierras. The apex is pyramidal, sharp, and clearly cut, leading to the inference that it is precipitous on the invisible northern side.

The whole of the great rock-face is marked by straight, rigid lines of bedding, which are inclined uniformly to the eastward, at an angle of about ten degrees.

There seemed to be but little snow on the upper portions of the mountain, though the lower peaks to the eastward were of a uniform white. We ascribed this to the topographical features which afford the wind every facility for carrying away any snow almost as rapidly as it falls. At the apex, there was no crater, nor any appearance of one; nor did any sign of smoke or steam appear in the vicinity of the mountain during the whole time it was visible to us.

Mount Fairweather presents somewhat similar characteristics. Like Elias, it is separated from the sea by a plateau, with a valley behind the latter parallel with the shore and the trend of the range. But the upper surface of this table-land is more irregular, and is covered in parts with a dense forest, which creeps up the side of the mountain for four thousand feet, and fades away near the snow-line. The mountain is more extended east and west than Saint Elias, and consists of a small, angular peak, with a long, high shoulder on either hand. The sides are seamed with rifts and valleys of denudation in whose lower parts at least four large glaciers were evident. The angular cliff-forming structure so marked in the Yosemite region of California, seemed especially to characterize this and its adjacent mountains. Their upper portions were abundantly supplied with snow; but here, again, was nothing which, by any stretch of the imagination, could be taken for a crater.

By a reference to the map, it will be seen that the portion of the range in which these great elevations occur is at the apex, so to speak, of a deep curve in the shore of the continent, forming what has been termed by the Coast Survey the Gulf of Alaska. The curve of the range is sharper than that of the coast, as lowlands intervene between the mountains and the shore. The greater pressure occurs in the region of sharper curves in all mountain-building, and here we have, as might naturally be expected, the greatest elevations on the continent in the region of unsurpassed mountain-folding.

The extraordinary roughness of the topography is, in a general way, the result of two systems of plication, subsidiary to the greater flexures of the range as a whole. One, the primary system, is of plications parallel to the axis of the range; and the other, a secondary system, with plications at right angles to that axis. The fissure valleys of the second series are less conspicuous than the more extensive but proportionately shallower folds of the first series. The main direction of the coast-line is coincident with the primary series. The chief features of the local topography are determined by the secondary series. Only the strongest of these cross, from the mountains, the inner primary folds, and form bays in the shore-line beyond.

Most of the glaciers for which this region is remarkable take origin in the snows of the higher elevations; are molded in the upper portion of the secondary valleys, and arriving at the first primary valley, are turned aside, and for the rest of their course run parallel with the axis of the mountains and the trend of the shore. A few, invariably the largest, find a path ready hewn for them in the stronger secondary valleys above mentioned, which conducts them across the first primary fold to the sea-shore. None of those on the main coast, betwen Cape Spencer and Point Rion, appear to cross the beach.

When the terminus of the secondary fold is sufficiently pronounced to form a deep bay, then the glacier may reach the water, and its cast-off fragments appear as mimic bergs. In these cases the slope is always much steeper and sharper than when the furrow is too wide to form a marked indentation of the shore-line.

In front of all glaciers which reach the sea, white discolored water is to be observed, but extensive shoals are not formed, the detritus being too fine to sink before being widely distributed. Where only

the torrents from the island glaciers are discharged, shoals are invariably present. This generalization is of wide application, and important in its bearings on the question of glaciation in general.

The character of the topography is such that it is inconceivable that a continuous glacier, moving in any direction, could have ever covered the western slope of these mountains. That it did not, we have abundant proof, which may more properly find a place elsewhere.

We are able to contribute some facts of importance to the knowledge of the material of which this range was built, and to the character of its peaks.

Wherever we were able to reach the bed-rock of the range, as at Lituya Bay and Port Mulgrave, we found it to be syenite, often associated with garnets. Here and there, as at Point Fairweather, apparently at points of greatest lateral pressure, were small, low craters, rarely conical, usually partaking more or less of the character of fissures, from which basalt and recent red lavas have been sparingly emitted. These small vents are near the bases of the mountains, and seldom greatly disturbed the horizontal Tertiary beds of sandstones and conglomerates which border on the mountain masses of syenite unconformably. The bare lowland which has been formed by subaerial and glacial wear, is often tinged with red by the lavas. The detritus overlies the Tertiary strata, but where the bed-rock of the range comes down to the sea, volcanic material is entirely absent from the talus. At Port Mulgrave, the lower portion of the foot-hills contains beds of limestone, metamorphosed into coarsely crystalline marble, such as was found farther south by the Coast Survey party of 1867 under Assistant George Davidson, and is not infrequent in the Sierras. There are also quartzites, much metamorphosed, underlying the nearly-horizontal and sparingly-fossiliferous Tertiary beds.

The conclusions, then, to which these facts would seem to lead us are as follows: That these Alps are, like the high Sierra of California, mainly composed of crystalline rocks, and in their topography, their small, pustular, basaltic vents, their associated marbles, quartzites, and later conglomerates, exhibit a close parallel to the Sierras; that parallelism in structure and composition implies parallelism in age and method of formation; and, finally, that the volcanic origin of the high peaks is opposed not only by analogy, but by the known facts. A glance at the accompanying sketches will lead any one familiar with the types of mountain structure toward the conclusion that these peaks are not of the volcanic type, and, even without confirmatory evidence, would lead to the suspicion that they were composed of crystalline rocks.

I do not doubt that small eruptions have taken place in comparatively recent times from the vents alluded to, which may have led unscientific observers to suppose that the peaks themselves were volcanic, especially if they examined only the detritus, which in some localities is largely composed of basalt and lava.

With regard to volcanic activity, I find no recorded observations of any relating to these peaks, except Saint Elias, and that only as follows. In a manuscript translation of Tebenkoff's hydrographic notes on this region (most of which, by the by, are incompatible with recent observations), I find this statement: "In 1839, Saint Elias peak began to send forth, occasionally, smoke and ashes from a crater on its northeast side. According to reports collected by Tebenkoff, during the earthquake in Sitka, in 1849, the peak of Saint Elias sent forth flame and ashes."—(Notes on Chart VII.)

Now, no civilized man has yet beheld the northeast side of Mount Saint Elias, and, therefore, if smoke and ashes appeared from that quarter, it could not have been determined whether they came from that mountain, or some lower peak beyond. But as there were at that time no civilized inhabitants at Yakutat, I agree with Grewingk, who had all the material before him, in placing no credence in the statements above quoted. After thorough search, I have been able to find no trustworthy account of any eruption. I was informed by one Russian that he had, on a voyage from Sitka, seen smoke and flame issuing from the peak of Saint Elias, and he gave a glowing account of the magnificent spectacle it presented. Another person, a passenger on the same voyage and vessel, afterward told me that indeed he had seen the mountain very plainly, but that the story of an eruption was a complete fiction. It is, therefore, not impossible that Tebenkoff might have been similarly deceived.

Grewingk, discussing the same question, argues that since no trustworthy account exists of an eruption, it becomes unsafe to assert that it has occurred, and suggests that it may be placed in the same category with a volcano reported by Spanish navigators on Cape Mendocino, which has long

since been proved to have no existence. He says: "Though Saint Elias stands in the volcanic line of Iliamna, Nunivak, and Saint Mathew's Island, nevertheless we believe its volcanic nature may justly be doubted, since the absence of a crater or conical form, and its ragged crest, make it very probable that it has never been penetrated by a volcanic chimney."

* * * "The proximity of the active volcano of Wrangell to Saint Elias renders it improbable that the subterranean fires would seek, so near, an indubitably difficult egress through the giant of American mountains."

The great height of Saint Elias is also opposed to its asserted volcanic nature, and the recent determination of the sedimentary (Cretaceous) structure of Aconcagua and other high peaks of South America, which have always hitherto ranked among volcanoes, is worthy of being noted in the present connection.

We may, therefore, say, at least, that the presumption is in favor of the non-volcanic character of Saint Elias, and that the burden of proof rests with those who may still be inclined to assert its volcanic origin.

II.—DISCUSSION OF THE DATA.

In the computations accompanying this report are given, first, all the data necessary to the computer, followed by the computations of the positions of the peaks in question; and, lastly, the computations of the heights, resulting from the vertical angles and double-zenith distances measured on the several peaks, and their computed distances from the points at which the observations were taken.

Hence, any one, with the data here furnished, can pursue the computations according to the method he may prefer, and have all the material necessary for forming an independent judgment on the value of our results.

The mountains referred to are Mount Crillon, Mount Fairweather; two peaks of great height in the range to the eastward of Mount Saint Elias, now first named by the United States Coast Survey Mount Cook and Mount Vancouver, respectively, and Mount Saint Elias itself. The means by which the positions of these mountains were obtained are of different values. Mount Crillon was determined by a triangulation from Lituya Bay, connected with a measured base and an astronomically-determined azimuth line. The angle at the peak was of course unobserved, and being very small, I regard the results as of only secondary value.

Mount Fairweather was determined by horizontal angles, referred to an astronomical azimuth from the astronomical stations at Lituya Bay and Port Mulgrave. The angle of intersection, though not observed, being not far from a right angle, the included error cannot greatly affect the computation for position, and I believe the results to be as satisfactory as the method will allow.

The positions of Mounts Cook and Vancouver were determined by horizontal angles, referred to the azimuth line from the astronomical station at Port Mulgrave, and intersected by bearings taken from the vessel when in a well-determined position in the western portion of the Bay of Yakutat. The intersecting angles are moderately large, but the method is much less satisfactory than if both angles had been measured with the theodolite, and I regard the results as approximate only.

The position of Mount Saint Elias was fixed by horizontal angles connected with the azimuth ine at Port Mulgrave, by azimuth observations taken directly on the peak from a well-determined sea-position, and by confirmatory bearings from a very well determined sea-position at Dry Bay. The latter, however, have not been used in the computations.

The unobserved angle being nearly 60°, the liability to error is reasonably small.

Our position for the mountain is within a third of a mile of that assigned to it by Captain Cook, and is, in my opinion, sufficiently satisfactory to remove any doubt as to the probability of serious error arising in the results from uncertainty of position.

The vertical angles for elevation are also of different classes.

The first of these comprises sextant-angles. Except under the most favorable circumstances, and especially unless within a comparatively short distance of the object measured, I do not consider these as being of any great value.

The uncertainties of position and refraction are so great as to render the result in most cases of only the most general character. I have, therefore, rejected a large number of these observations. Those which I have admitted, in most cases, I do not consider of sufficient precision to unite with the results of vertical-circle or theodolite observations for the purpose of obtaining a mean.

In one case only—that of Mount Fairweather, where the elevation was measured from well-determined positions close to the base of the mountain, and not far from the stations at which the other class of observations were obtained—have I ventured to use them in such a manner.

I have inserted some computations of such observations in separate columns; but, with the exception already noted, rather as a matter of curiosity than as a source of reliable information.

Mount Crillon was measured from five or six different points with the sextant. I have given the best of these observations, but place no confidence in them. It was also measured from Lituya Bay with the theodolite, and were it not for the extremely small angle of intersection, which throws some doubt on the position, I should be tolerably well satisfied with the resulting height. The impression made on our minds from viewing this mountain from a multitude of positions was that it is slightly higher than Mount Fairweather. I think it probable that when better observations are practicable it may be found a few hundred feet lower than our theodolite-determination.

Mount Fairweather was measured from Lituya Bay by theodolite and from Port Mulgrave by vertical-circle observations of double-zenith distances; also, from a number of points close to Lituya Bay by sextant-angles.

The mean of all the Lituya Bay observations is	15,462 feet.
The mean of all observations with sextant is	15,443 feet.
The mean of vertical-circle and theodolite observations is	15,388 feet.
The mean of all observations is	15,423 $\pm$ 120.

And this result, I am convinced, is not far from the truth.

The altitudes of Mounts Cook and Vancouver were determined by a series of double-zenith distances, observed at the Port Mulgrave astronomical station, and the resulting heights are regarded by me as approximate only, because of the doubt resting on the precision of the compass-bearings, by which, partly, their positions were determined.

Mount Saint Elias was measured by a particularly large series of double-zenith distances from Port Mulgrave, and also by a large number of sextant-observations from various localities. Part of the latter have been computed for the sake of showing that all the observations point to a greater height than has been previously claimed for the mountain. I give them no weight in the result, as they were all taken at great distances from the peak, and subject to various disturbing influences and uncertainty in most of the positions.

It has occurred to me, in view of the unanimity in the Lituya Bay observations, that we might apply the difference between the height of Mount Fairweather, as there obtained, and that obtained from Port Mulgrave, in the ratio of the square of the distances, as a correction for the undetermined error of the refraction in the case of Mount Saint Elias.

All the Port Mulgrave observations were taken about the same time, at the same place, with the same instrument, and subject to the same influences. As the mean of the Lituya observations on Fairweather is greater than the result of the Port Mulgrave observations, the correction for Mount Saint Elias would be additive. The ratio being $147,907.24^2 : 111,212.1^2 :: 192 : 108.5$, which is the resulting correction for Saint Elias, 192 feet being the difference between the two series on Mount Fairweather. The height of Saint Elias, as obtained at Port Mulgrave, being 19,464 feet, when corrected it would be 19,572 feet.

Unfortunately, Port Mulgrave is so completely encircled by land as to have rendered it impossible to obtain a back sight at the opposite sea-horizon, which would have given us an approximation to the true refraction. In the following computations, 0.08 has been taken as the coefficient, which is nearly the average found in the ordnance survey of Great Britain, with a not very dissimilar latitude and climate. The observations of all kinds have been computed by Coast Survey methods. The heights have been computed by a special formula supplied by Assistant C. A. Schott, chief of the computing division. The formulas for the computation of distances are from Appendix

No. 36, Coast Survey L. M. Z. tables, computed inversely; the radius of curvature from Appendix No. 11, Coast Survey Report 1871, carried out to 60° north latitude.

The computations have been made by Mr. Marcus Baker and reviewed by Mr. Schott.

I would recommend for adoption the following values:

Mount Saint Elias	19,500 feet ± 400 feet.
Mount Cook	16,000 feet approximately.
Mount Vancouver	13,100 feet approximately.
Mount Fairweather	15,500 feet ± 150 feet.
Mount Crillon	15,900 feet ± 500 feet.

The accompanying sketch-map will facilitate the comprehension of the data for computation and the method employed.

REDUCTION OF OBSERVATIONS MADE IN 1874 BY ACTING ASSISTANT W. H. DALL AND PARTY, TO DETERMINE THE HEIGHTS OF MOUNT SAINT ELIAS, COOK, CRILLON, FAIRWEATHER, AND VANCOUVER.

All the longitudes used in these reductions depend upon 6 chronometers, rated at Sitka May 5, and again at Kadiak June 6, 1874. The rates of the chronometers are assumed uniform during this interval.

The corrections to the chronometers at Sitka depend upon 24 pairs of equal altitudes of the sun, measured with the sextant and artificial horizon.

The corrections to the chronometers at Kadiak depend upon 46 pairs of equal altitudes of the sun, measured with the sextant and artificial horizon.

1. Lituya Bay. Time depends upon 33 pairs of equal altitudes of the sun; latitude depends upon 44 single altitudes of the sun with the sextant and artificial horizon; azimuth depends upon 7 sets, of 6 each, of observations upon the sun with C. S. theodolite No. 97. Five of these sets were observed and reduced by the method given in ¶ 16, Appendix 11, to the Coast Survey Report of 1866, by Assistant Schott, and two sets by ¶ 19 of the same Appendix.

2. Port Mulgrave. Time depends upon 33 pairs of equal altitudes of the sun; latitude depends upon 18 altitudes of the sun with the sextant, and 32 double zenith distances with Gambey vertical-circle No. 75; azimuth depends upon 8 sets, of 6 each, of observations upon the sun, with C. S. theodolite No. 97, and by method 16 of the Appendix above referred to.

3. Station "At sea," upon which the position of Mount Saint Elias depends. Time depends upon 12 altitudes of the sun from sea-horizon; latitude reckoned by log from noon; determined at noon by the usual sextant-observations; azimuth depends upon two sets, of 5 each, of observations upon the sun. The angular distance of the sun from Mount Saint Elias was measured with the sextant, and the time noted. From the known latitude and hour-angle the altitude and azimuth were deduced, and from these the azimuth of Mount Saint Elias.

In all the observations with the sextant the *index-correction* has been determined in connection with each series of observations and properly allowed for, and, also, proper allowance has been made for *dip*, *parallax*, and *refraction*, including the barometric and thermometric factors.

In all the sextant-work the sextant used is No. 95, by Troughton & Simms, of London.

The adjustments of all the instruments used have been constantly examined and found correct, and the instruments kept level whenever used. And wherever the principle of reversal has been available for the elimination of error, it has been employed.

Mounts Cook and Vancouver are determined in position only approximately. The determination was made as follows: The true bearing of the magnetic mark from the astronomical station was determined astronomically, and the angles between the mountains and the mark measured with theodolite No. 97. This gave the true bearing of the mountains from Ast. △, Port Mulgrave. When the vessel left Port Mulgrave and had reached the mouth of Yakutat Bay, its position was fixed by compass-bearings upon objects determined by us on shore, and at the same time the compass-bearings of Mounts Cook and Vancouver were taken.

From these data, the mountains were platted upon a chart made from our own observations, and the resulting latitudes and longitudes were used in determining the distances of the mountains.

REDUCTION OF OBSERVATIONS FOR ALTITUDE OF MOUNT FAIRWEATHER.

	° ′ ″	″
The astronomical station at Lituya Bay is in longitude	+ 137 40 04.6 ±	10.6
and latitude	+ 58 36 57.0 ±	1.2
The azimuth of the line Astronomical △ to Village △ is	+ 175 41 08.0 ±	4.4
The angle at Astronomical △, between Village △ and Woody Point △, is	+ 98 21 15.	
The azimuth of the line Astronomical △ to Woody Point △ is	+ 274 02 23.	
Woody Point △ is in longitude	+ 137 37 40.9	
and latitude	+ 58 36 51.7	
The azimuth of the line Woody Point △ to Astronomical △ is	+ 94 04 25.6	
The angle at Woody Point △, between Astronomical △ and Mount Fairweather, is	+ 97 05 55.	
The azimuth of the line Woody Point △ to Mount Fairweather is	+ 191 10 20.6	
The azimuth of the line Woody Point △ to Astronomical △, Port Mulgrave, is	+ 131 33 26.44	
The distance from Woody Point △ to Mount Fairweather is	33184.53^{m}	
The vertical angle of Mount Fairweather from Woody Point △ is	7 58 40.	
The vertical angle was measured at 2 p. m., May 15, 1874: Barometer, 30.11; attached thermometer, 75° Fahrenheit; external thermometer, 59° Fahrenheit.		
The astronomical station at Port Mulgrave is in longitude	+ 139 46 15.9 ±	18.3
and latitude	+ 59 33 42.0 ±	2.1
The azimuth of the line Astronomical △, Port Mulgrave, to Magnetic Mark, is	+ 133 24 57.5 ±	6.7
The angle at Astronomical △, Port Mulgrave, between Mount Fairweather and Magnetic Mark, is	165 08 35.	
The azimuth of the line Astronomical △, Port Mulgrave to Mount Fairweather, is	298 33 32.5	
The azimuth of the line Astronomical △, Port Mulgrave to Woody Point △, is	309 43 07.3	
The distance from Astronomical △, Port Mulgrave, to Woody Point △, is	161895.56^{m}	
The distance from Astronomical △, Port Mulgrave, to Mount Fairweather, is	147907.24^{m}	
The zenith distance of Mount Fairweather from Astronomical △, Port Mulgrave, is	88 45 17.1	

The zenith distance was measured with Gambey vertical-circle No. 75, at 6 p. m., May 23, 1874: Barometer at 6 p. m., 29.92; attached thermometer, 68° Fahrenheit; external thermometer, 64° Fahrenheit.

Triangulation at Lituya Bay.

Denomination.	Observed angles.	Corr.	Plane angles and distances.	Logarithms.
Astronomical △ to Village △ = base	....	....	413. 789	2. 6167790
Woody Point △	9° 44′ 30″	— 1″	9° 44′ 29″	0. 7715961
Astronomical △	98 21 16. 8	— 1. 8	98 21 15	9. 9953671
Village △	71 54 17. 5	— 1. 5	71 54 16	9. 9779703
Village △ to Woody Point △	....	....	2419. 590	3. 3837422
Woody Point △ to Astronomical △	....	....	2324. 585	3. 3663454

Determination of position of Woody Point △.

		°	′	″
Z	Astronomical station to Village △	175	41	08
∠	Village △ and Woody Point △	98	21	15
Z	Astronomical station to Woody Point △	274	02	23
dZ	....	......	+ 2	02. 6
180°	....	......	......	......
Z′	Woody Point △ to Astronomical station	94	04	25. 6

	°	′	″			°	′	″
L	58	36	57. 0	Astronomical station........	M	137	40	04. 6
dL	......	......	— 5. 315	2324m.585	dM	......	— 2	23. 665
L′	58	36	51. 685	Woody Point △	M′	137	37	40. 945

λ = 58° 36′ 54″		K	3. 3663454	K²	6. 73269	......	....
		B	8. 5095133	C	1. 61744	D	....
		cos Z	8. 8478690	sin Z	9. 99784	h²	....
1st term.	+5″. 293	h	0. 7237277	....	8. 34797	......	....
2d and 3d terms.	+ . 022						
— dL	+5 . 315						

K	3. 3663454	....	....
sin Z	9. 9989197n	.. ..	....
A′	8. 5087229	dM	2. 15732n
cos L′ ar. comp.	0. 2833326	sin λ	9. 93130
	2. 1573206n	....	2. 08862n
dM	— 143″. 655	—dZ	— 122″. 6

Computation of distance from Woody Point △, Lituya Bay, to Astronomical △, Port Mulgrave.

		°	′	″
Z	............to	......	......	......
∠	............and	......	......	......
Z	Woody Point △, Lituya Bay, to Astronomical △, Port Mulgrave...	131	33	26. 44
d Z	....	− 1	50	19. 10
180°	....	......	......	......
Z′	Astronomical △, Port Mulgrave, to Woody Point △, Lituya Bay...	309	43	07. 34

	°	′	″			°	′	″
L	58	36	51. 685	Woody Point △, Lituya Bay	M	137	37	40. 945
d L	......	+56	50. 315	161895m.56 = 100.59 statute miles	d M	+ 2	08	34. 955
L′	59	33	42. 000	Astronomical △, Port Mulgrave	M′	139	46	15. 900

λ = 59° 05′ 17″		B	8. 5095135	C	1. 61741	D	2. 3372
		K cos Z	5. 0309903n	K² sin² Z	0. 16661	h²	7. 0809
1st term.	− 3471″. 393	h	3. 5405038n	....	1. 78402	....	9. 4181
2d and 3d terms.	+ 61 . 078				60. 816	....	0. 262
−d L	− 3410 . 315						
				sin Z	9. 8740712	cos Z	9. 8217554n
				K sin Z	5. 0833061	K cos Z	5. 0309903n
				K	5. 2092349	K	5. 2092349

Z	− 48° 26′ 33″. 56	....	....
tg Z	0. 0523158n	....	....
K cos Z	5. 0309903n	....	....
K sin Z	5. 0833061	....	....
A′	8. 5087016	d M	3. 8873334
cos L′ ar. comp.	0. 2953257	sin λ	9. 9334659
	3. 8873334	....	3. 8207993
d M	+ 7714″. 955	−d Z	+ 6619″. 10

SOLUTION OF TRIANGLE MOUNT FAIRWEATHER, WOODY POINT △, AND ASTRONOMICAL △ PORT MULGRAVE.

	° ′ ″		
Z Woody Point △ to Astronomical △, Lituya Bay	94 04 25.6		
∠ Astronomical △ and Mount Fairweather	97 05 55		
		° ′ ″	
Z Woody Point △ to Mount Fairweather		191 10 20.6	
Z Woody Point △ to Astronomical △ Port Mulgrave		131 33 26.44	
			° ′ ″
∠ At Woody Point △ between Astronomical △ Port Mulgrave and Mount Fairweather .... (A)			59 36 54.2
Z Astronomical △ to Magnetic Mark, Port Mulgrave...	133 24 57.5		
∠ Magnetic Mark and Mount Fairweather	165 08 35.		
Z Astronomical △ Port Mulgrave to Mount Fairweather............		298 33 32.5	
Z Astronomical △ Port Mulgrave to Woody Point △, Lituya Bay....		309 43 07.34	
∠ At Astronomical △ Port Mulgrave between Woody Point △, Lituya Bay, and Mount Fairweather .... (B)			11 09 34.8
180° − (A + B) .... (C)			109 13 31.0

Denomination.	Plane angles and distances.	Logarithms.
Woody Point △ to Astronomical △ Port Mulgrave	161895^{m}.56	5.2092349
Mount Fairweather (C)	109° 13′ 31″.0	0.0249216
Astronomical △ Port Mulgrave (B)	11 09 34 .8	9.2867792
Woody Point △ (A)	59 36 54 .2	9.9358329
Astronomical △ Port Mulgrave to Mount Fairweather ...	147907^{m}.24	5.1699894
Mount Fairweather to Woody Point △	33184.53	4.5209357

Determination of position of Mount Fairweather.

		°	′	″
Z	Woody Point △, Lituya Bay, to Astronomical △, Lituya Bay...	94	04	25.6
/	Astronomical △, Lituya Bay, and Mount Fairweather	97	05	55
Z	Woody Point △, Lituya Bay, to Mount Fairweather............	191	10	20.6
d Z	....	......	+ 5	43.4
180°	....	......	......	....
Z′	Mount Fairweather to Woody Point △, Lituya Bay............	11	16	04.0

	°	′	″			°	′	″
L	58	36	51.685	Woody Point △, Lituya Bay....	M	137	37	40.945
d L	......	+17	32.105	33184m.53..........................	d M	......	− 6	41.702
L′	58	54	23.790	Mount Fairweather............	M′	137	30	59.243

		K	4.5209357	K²	9.04187	....	....
λ = 58° 45′ 37″.7		B	8.5095135	C	1.61741	D	2.3372
		cos Z	9.9916906n	sin² Z	8.57453	h²	6.0443
1st term.	−1052″.300	h	3.0221398n	....	9.23381	....	8.3815
2d and 3d terms.	+ .195				.1713	....	.0241
−d L	−1052 .105						

K	4.5209357	....	....
sin Z	9.2872677n	....	....
A′	8.5087163	d M	2.60390n
cos L′ ar.-comp.	0.2869847	sin λ	9.93197
	2.6039044n	....	2.53587n
d M	−401″.702	−d Z	−343″.4

Computation of distance from Mount Fairweather to "Off Cape Spencer."

		°	′	″
Z	.... to..	......	......	....
∠	.... and..	......	......	....
Z	Mount Fairweather to "Off Cape Spencer"	350	01	34. 60
d Z	....	......	+12	46. 98
180°	....	......	......	....
Z′	"Off Cape Spencer" to Mount Fairweather............................	170	14	21. 58

	°	′	″			°	′	″
L	58	54	23. 790	Mount Fairweather......................	M	137	30	59. 243
d L	......	–45	03. 790	84902m.75	d M	......	–14	59. 243
L′	58	09	20	"Off Cape Spencer"	M′	137	16	00. 000

$\lambda = 58° 31' 52''$		B	8. 5094937	C	1. 622381	D	2. 3349
		K cos Z	4. 9223083	K² sin² Z	8. 33492	h^2	6. 8636
1st term.	+2702″. 726	h	3. 4318020	....	9. 95730	....	9. 1985
9d and 3d terms.	+ 1 . 064				0. 906	....	0. 158
–d L	+2703 . 790						
				sin Z	9. 2385391*n*	cos Z	9. 9933865
				K sin Z	4. 1674608*n*	K cos Z	4. 9223083
				K	4. 9289217	K	4. 9289218

Z	–9° 58′ 25″. 40	....	....
tg Z	9. 2451525*n*	....	....
K cos Z	4. 9223083	....	....
K sin Z	4. 1674608*n*	....	....
A′	8. 5087333	d M	2. 953877*n*
cos L′	0. 2776829	sin λ	9. 930910
ar. comp.			
	2. 9538770*n*	....	2. 884787*n*
d M	–899″. 243	–d Z	–766″. 98

Computation of distance from Mount Fairweather to "Off Lituya Bay.

		°	′	″
Z	.... to	.....	.....	......
L	.... and	.....	.....	......
Z	Mount Fairweather to "Off Lituya Bay"	17	47	52. 33
d Z	....	.....	— 9	50. 54
180°	....	.....	.....	......
Z′	"Off Lituya Bay" to Mount Fairweather	197	38	01. 79

	°	′	″			°	′	″
L	58	54	23. 790	Mount Fairweather	M	137	30	59. 243
d L	.....	—18	43. 790	36498^m.76	d M	.....	+11	30. 757
L′	58	35	40	"Off Lituya Bay"	M′	137	42	30

λ = 58° 45′ 02″		B	8. 5094937	C	1. 622381	D	2. 3349
		K cos Z	4. 5409793	K² sin² Z	8. 095033	h^2	6. 1009
1st term.	+1123″. 241	h	3. 0504730	....	9. 717414	....	8. 4358
2d and 3d terms.	+ .549				0. 5217	....	. 0273
d L	+1123 . 790						
				sin Z	9. 4852385	cos Z	9. 9787011
				K sin Z	4. 0475167	K cos Z	4. 5409793
				K	4. 5622782	K	4. 5622782

Z	17° 47′ 52″. 33	....	....
tg Z	9. 5065374	....	....
K cos Z	4. 5409793	....	....
K sin Z	4. 0475167	....	....
A′	8. 5087233	d M	2. 839325
cos L′	0. 2830853	sin λ	9. 931924
ar. comp.			
	2. 8393253	....	2. 771249
d M	+690″. 757	—d Z	+590″. 54

Computation of distance from Mount Fairweather to "Off Lituya, May 19."

		°	′	″
Z	.... to	......	......	....
∠	.... and	......	......	....
Z	Mount Fairweather to "Off Lituya, May 19"	29	57	40. 5
dZ	....	......	−19	40. 2
180°	....	......	......	....
Z′	"Off Lituya, May 19," to Mount Fairweather	209	38	00. 3

	°	′	″			°	′	″
L	58	54	23. 790	Mount Fairweather	M	137	30	59. 243
dL	.....	−20	53. 790	$44698^m.72$	dM	......	+23	00. 757
L′	58	33	30	"Off Lituya, May 19"	M′	137	54	00. 000

λ = 58° 43′ 57″		B	8. 5094937	C	1. 622381	D	2. 3349
		K cos Z	4. 5879951	$K^2 \sin^2 Z$	8. 697512	h^2	6. 1950
1st term.	+1251″. 667	h	3. 0974888	....	0. 319893	....	8. 5299
2d and 3d terms.	+ 2 . 123				2. 0888	....	. 0339
−dL	+1253 . 790						
				sin Z	9. 6984608	cos Z	9. 9377001
				K sin Z	4. 3487559	K cos Z	4. 5879951
				K	4. 6502951	K	4. 6502950

Z	29° 57′ 40″. 49	....	....
tg Z	9. 7607608	....	....
K cos Z	4. 5879951	....	....
K sin Z	4. 3487559	....	....
A′	8. 5087241	d M	3. 140117
cos L ar. comp.	0. 2826373	sin λ	9. 931841
	3. 1401173	....	3. 071958
d M	+1380″. 757	−d Z	+1180″. 2

Computation of height of Mount Fairweather.

Set.	Off Cape Spencer.	Off Lituya Bay.	Off Lituya, May 19.	Woody Point Δ Lituya.	Astronomical Δ. Port Mulgrave.
	1	2	3	4	5
ζ	87° 01′ 54″. 3	82° 53′ 02″. 7	84° 17′ 51″. 0	82° 01′ 20″. 0	88° 45′ 17″. 1
log s	4. 9289217	4. 5622782	4. 6502950	4. 5209357	5. 1699894
log cot ζ	8. 7147666	9. 0963493	8. 9993800	9. 1465787	8. 3372023
log 1st term	3. 6436883	3. 6586275	3. 6496750	3. 6675144	3. 5071917
log $\frac{1}{2}$ (1 − 2 m) = log . 42	9. 6232493	9. 6332493	9. 6232493	9. 6232493	9. 6232493
log s^2	9. 8578434	9. 1245564	9. 3005900	9. 0418714	0. 3399788
a. c. log ρ	3. 195012	3. 194946	3. 194823	3. 194988	3. 194392
log 2d term	2. 6761047	1. 9427517	2. 1186623	1. 8601087	3. 1576201
log (1 − m) = log .92	9. 9637878	9. 9637878	9. 9637878	9. 9637878	9. 9637878
log [1st term]^2	7. 2873766	7. 3172550	7. 2993500	7. 3350288	7. 0143834
a. c. log ρ	3. 195012	3. 194946	3. 194823	3. 194988	3. 194392
log 3d term	0. 4461764	0. 4759888	0. 4579608	0. 4938046	0. 1725632
1st term	4402. 388	4556. 459	4463. 495	4650. 658	3215. 079
2d term	474. 356	87. 650	131. 420	72. 462	1437. 540
3d term	2. 794	2. 992	2. 870	3. 117	1. 488
h	4879. 538	4647. 101	4597. 785	4726. 237	4654. 107
log h	3. 6883787	3. 6671821	3. 6625487	3. 6745155	3. 6678363
constant	0. 5159929	0. 5159929	0. 5159929	0. 5159929	0. 5159929
log h in feet	4. 2043716	4. 1831750	4. 1785416	4. 1905084	4. 1838292
h in feet	16009.	15247.	15085.	15506.	15270.

Set 1. Mean of six altitudes from sea-horizon with Troughton sextant, No. 95. Instrument in adjustment.
Set 2. One altitude from sea-horizon with Troughton sextant, No. 95. Instrument in adjustment.
Set 3. Mean of eight altitudes from sea-horizon with Troughton sextant, No. 95. Instrument in adjustment.
Set 4. Mean of twelve altitudes, six direct and six reversed, with Casella theodolite, No. 3300, in adjustment and leve.
Set 5. Mean of nine double-zenith distances, with Gambey vertical-circle, No. 75, in adjustment and level.

Reduction of observations for height of Mount Crillon.

TRIANGULATION AT LITUYA BAY.

Denomination.	Observed angles.	Corr.	Plane angles and distances.	Logarithms.
Woody Point Δ to Village Δ	....	......	2419. 590	3. 3837122
Mount Crillon	rem. 180°	......	1° 32′ 34″	1. 5698717
Woody Point Δ	155° 59′ 40″	....	155 59 40	9. 6094079
Village Δ	22 27 46⅜	−⅜″	22 27 46	9. 5821579
Village Δ to Mount Crillon	....	....	36561. 3	4. 5630218
Mount Crillon to Woody Point Δ	....	......	34337. 75	4. 5357718

		°	′	″
Woody Point Δ is in longitude	+	137	37	40. 9
and latitude	+	58	36	51. 7
The azimuth of the line Woody Point Δ to Astronomical Δ is	+	94	04	25. 6
The angle at Woody Point Δ between Astronomical Δ and Mount Crillon is		165	44	09.
The vertical angle on Mount Crillon from Woody Point Δ is		7	55	37. 5

Measured at 2.30 p. m., May 15, 1874. Barometer, 30.11; attached thermometer, 75° Fahrenheit; external thermometer, 59° Fahrenheit.

Determination of position of Mount Crillon.

		°	′	″
Z	Woody Point Δ to Astronomical station	94	04	25. 6
∠	Astronomical station and Mount Crillon	165	44	09
Z	Woody Point Δ to Mount Crillon	259	48	34. 6
d Z	......	......	+29	50. 4
180°	......	......	......	......
Z′	Mount Crillon to Woody Point Δ	80	18	25. 0

	°	′	″			°	′	″
L	58	36	51. 685	Woody Point Δ	M	137	37	40. 945
d L	......	+ 3	11. 631	34337m.75	d M	......	− 34	56. 924
L′	58	40	03. 316	Mount Crillon	M′	137	02	44. 021

$\lambda = 58° 37' 57''$		K	4. 5357718	K²	9. 07154	......	....
		B	8. 5095135	C	1. 61741	D	....
		cos Z	9. 2177760*n*	sin² Z	9. 98619	h²	....
1st term.	−196″.364	h	2. 2930613*n*	....	0. 67514	......	....
2d and 3d terms	+ 4.733						
−d L	−191.631						

K	4. 5357718	....	....
sin Z	9. 9930945*n*	....	....
A′	8. 5087217	d M	3. 32158*n*
cos L′	0. 2839947	sin λ	9. 93138
ar. comp.			
	3. 3215827*n*	....	3. 25296*n*
d M	−2096″.924	−d Z	−1790″.4

Computation of distance from Mount Crillon to "Off Cape Spencer."

		°	′	″
Z	............to............	......	......	......
∠	............and............	......	......	......
Z	Mount Crillon to "Off Cape Spencer"............	12	51	44. 29
d Z	....	......	−11	18. 04
180°	....	......	......	......
Z′	"Off Cape Spencer" to Mount Crillon............	192	40	26. 25

	°	′	″			°	′	″
L	58	40	03. 316	Mount Crillon	M	137	02	44. 021
d L	....	−30	43. 316	$58471^{m}.38$	d M	......	+13	15. 979
L′	58	09	20. 000	"Off Cape Spencer"	M′	137	16	00. 000

$\lambda = 58° 24′ 42″$		B	8. 5095099	C	1. 618312	D	2. 33680
		K cos Z	4. 7559068	K² sin² Z	8. 228971	h^2	6. 53083
1st term.	+1842″.539	h	3. 2654167	....	9. 847283	....	8. 86763
2d and 3d terms.	+ .777				. 7035	....	. 0737
− d L	+ 1843.316						
				sin Z	9. 3475421	cos Z	9. 9889635
				K sin Z	4. 1144854	K cos Z	4. 7559068
				K	4. 7669433	K	4. 7669433

Z	12° 51′ 44″. 29	....	....
tg Z	9. 3585786	....	....
K cos Z	4. 7559068	....	....
K sin Z	4. 1144854	....	....
A′	8. 5087333	d M	2. 900902
cos L′ ar. comp.	0. 2776829	sin λ	9. 930354
	2. 9009016	....	2. 831256
d M	+ 795″. 979	− d Z	+ 678″. 04

Computation of distance from Mount Crillon to "Off Lituya."

		°	′	″
Z	..............to..............................	....	.....	....
∠	..............and..............................	....	.....	....
Z	Mount Crillon to "Off Lituya"........................	78	20	06. 6
d Z	....	.....	− 33	57. 2
180°	....	.....	.....	......
Z′	"Off Lituya" to Mount Crillon........................	257	46	09. 4

	°	′	″			°	′	″
L	58	40	03. 316	Mount Crillon	M	137	02	44. 021
d L	......	-- 4	23. 316	39347ᵐ.88........................	d M	......	+39	45. 979
L′	58	35	40	"Off Lituya"........................	M′	137	42	30. 000

λ = 58° 37′ 52″		B	8. 5095099	C	1. 618312	D	2. 33680
		K cos Z	3. 9006732	K² sin² Z	9. 171716	h²	4. 82037
1st term.	+257″. 148	h	2. 4101831	....	0. 790028	....	7. 15717
2d and 3d terms.	+ 6 . 168				6. 1663	....	. 0014
−d L	+263 . 316						
				sin Z	9. 9909366	cos Z	9. 3057518
				K sin Z	4. 5858580	K cos Z	3. 9006732
				K	4. 5949214	K	4. 5949214

Z	78° 20′ 06″. 58	....	....
tg Z	0. 6851848	....	....
K cos Z	3. 9006732	....	....
K sin Z	4. 5858580	....	....
A′	8. 5087233	d M	3. 377667
cos L′ ar. comp.	0. 2830853	sin λ	9. 931373
	3. 3776666	....	3. 309040
. d M	+2385″. 979	−d Z	+2037″. 2

Computation of distance from Mount Crillon to "Off Lituya May 19th."

		°	′	″
Z	..............to..	.....	.....	....
∠	..............and..	.....	.....	....
Z	Mount Crillon to "Off Lituya May 19th"........................	76	35	47. 93
d Z	....	.....	— 43	45. 87
180°	....	.....	.....	....
Z′	"Off Lituya May 19th" to Monnt Crillon........................	255	52	02. 06

	°	′	″			°	′	″
L	58	40	03. 316	Mount Crillon	M	137	02	44. 021
d L	.....	— 6	33. 316	$51122^{m}.86$	d M	.....	+51	15. 979
L′	58	33	30. 000	"Off Lituya May 19th"	M′	137	54	00. 000

$\lambda = 58° 36' 46''.7$		B	8. 5095099	C	1. 618312	D	2. 33680
		K cos Z	4. 0737376	$K^2 \sin^2 Z$	9. 393244	h^2	5. 16649
1st term.	+383″. 043	*h*	2. 5832475	....	1. 011556	....	7. 50329
2d and 3d terms.	+ 10 . 273				10. 2697	....	. 0032
—d L	+393 . 316						
				sin Z	9. 9880068	cos Z	9. 3651225
				K sin Z	4. 6966219	K cos Z	4. 0737376
				K	4. 7086151	K	4. 7086151

Z	76° 35′ 47″. 93	....	....
tg Z	0. 6228843	....	....
K cos Z	4. 0737376	....	....
K sin Z	4. 6966219	....	....
A′	8. 5087241	d M	3. 4879833
cos L′ ar. comp.	0. 2826373	sin λ	9. 9312898
	3. 4879833	....	3. 4192731
d M	+3075″. 979	—d Z	+2625″. 87

Computation of height of Mount Crillon.

Set.	Off Cape Spencer. 1	Off Lituya Bay. 2	Off Lituya Bay May 19. 3	Woody Point △, Lituya. 4
ζ	86° 00′ 52″. 7	83° 29′ 52″. 7	85° 19′ 30″. 1	82° 04′ 22″. 5
log s	4. 7669433	4. 5949214	4. 7086151	4. 5357718
log cot ζ	8. 8430462	9. 0567961	8. 9126217	9. 1437743
log 1st term	3. 6099895	3. 6517175	3. 6212368	3. 6795461
log $\frac{1}{2}$ $(1-2\,m)$ = log .42	9. 6232493	9. 6232493	9. 6232493	9. 6232493
log s^2	9. 5338866	9. 1898428	9. 4172302	9. 0715436
a. c. log ρ	3. 195003	3. 194263	3. 194273	3. 194251
log 2d term	2. 3521389	2. 0073551	2. 2347525	1. 8890439
log $(1-m)$ = log .92	9. 9637878	9. 9637878	9. 9637878	9. 9637878
log (1st term)^2	7. 2199790	7. 3034350	7. 2424736	7. 3590922
a. c. log ρ	3. 195003	3. 194263	3. 194273	3. 194251
log 3d term	0. 3787698	0. 4614858	0. 4005344	0. 5171310
1st term	4073. 70	4484. 54	4180. 58	4781. 30
2d term	224. 98	101. 71	171. 69	77. 45
3d term	2. 39	2. 89	2. 51	3. 29
h	4301. 07	4589. 14	4354. 78	4862. 04
log h	3. 6335765	3. 6617313	3. 6389662	3. 6868186
const.	0. 5159929	0. 5159929	0. 5159929	0. 5159929
log h in feet	4. 1495694	4. 1777242	4. 1549591	4. 2028115
h in feet	14111.	15056.	14287.	15952.

Set 1. Mean of six altitudes from sea-horizon with Troughton sextant, No. 95, in adjustment.

Set 2. One altitude from sea-horizon with Troughton sextant, No. 95, in adjustment.

Set 3. Mean of eleven altitudes from sea-horizon with Troughton sextant, No. 95, in adjustment.

Set 4. Mean of twelve altitudes, six direct and six reversed, with Casella theodolite, No. 3300, in adjustment and level.

REDUCTION OF OBSERVATIONS FOR HEIGHT OF MOUNT SAINT ELIAS.

	° ′ ″	″
The astronomical station Port Mulgrave is in longitude	+ 139 46 15.9	± 18.3
and latitude	+ 59 33 42.0	± 2.1
The azimuth of the line Astronomical △ Port Mulgrave to Magnetic Mark is	+ 133 24 57.5	± 6.7
The angle at Astronomical △ Port Mulgrave between Magnetic Mark and Mount Saint Elias is	+ 8 52 20.	
The azimuth of the line Astronomical △ Port Mulgrave to Mount Saint Elias is	+ 142 17 17.5	
The azimuth of the line Astronomical △ Port Mulgrave to △ At sea is	+ 54 22 24.8	
The angle at Astronomical △ Port Mulgrave between Mount Saint Elias and △ At sea is	87 54 52.7	
The station At sea is in longitude	+ 142 14 01.	± 24.
and latitude	+ 58 37	
The azimuth of the line △ At sea to Mount Saint Elias is	+ 199 23 52.5	
The azimuth of the line △ At sea to Astronomical △ Port Mulgrave is	+ 232 15 38.8	
The angle at △ At sea between Mount Saint Elias and Astronomical △ at Port Mulgrave is	32 52 16.3	
The distance from △ At sea to Astronomical △ at Port Mulgrave is	176030^{m}.1	
The distance from △ At sea to Mount Saint Elias is	204768 .2	
The distance from Astronomical △ Port Mulgrave to Mount Saint Elias is	111212 .1	
The zenith distance of Mount Saint Elias from Astronomical △ Port Mulgrave is	87° 21′ 59″.0	

Measured at 6 p. m., May 23, 1874, with Gambey vertical-circle, No. 75; 18 repetitions. Barometer, 29.92; external thermometer, 64° Fahrenheit; attached thermometer, 68° Fahrenheit. Weather, clear; wind, calm. Altitude of ⊙ at time of observation = 17°.

SOLUTION OF TRIANGLE △ AT SEA, ASTRONOMICAL △ PORT MULGRAVE, AND MOUNT SAINT ELIAS.

	° ′ ″	° ′ ″
Z △ At sea to Astronomical △ Port Mulgrave	232 15 38.85	
Z △ At sea to Mount Saint Elias	199 23 22.5	
∠ At △ At sea between Mount Saint Elias and Astronomical △ Port Mulgrave (A)		32 52 16.35
Z Astronomical △ Port Mulgrave to Magnetic Mark	133 24 57.5	
∠ At Astronomical △ Port Mulgrave between Magnetic Mark and Mount Saint Elias	+ 8 52 20.	
Z Astronomical △ Port Mulgrave to Mount Saint Elias	142 17 17.5	
Z Astronomical △ Port Mulgrave to △ At sea	54 22 24.82	
∠ At Astronomical △ Port Mulgrave between △ At sea and Mount Saint Elias (B)		87 54 52.68
180° − (A + B) (C)		59 12 50.97

Denomination.	Plane angles and distances.	Logarithms.
Astronomical △ Port Mulgrave to △ At sea	176030^{m}.1	5.2455870
Mount Saint Elias (C)	59° 12′ 50″.97	0.0659632
Astronomical △ Port Mulgrave (B)	87 54 52.68	9.9997123
△ At sea (A)	32 52 16.35	9.7346018
△ At sea to Mount Saint Elias	204768^{m}.2	5.3112625
Mount Saint Elias to Astronomical △ Port Mulgrave	111212.1	5.0461520

Computation of distance from △ At sea to Astronomical △ Port Mulgrave.

		°	′	″
Z	............to...	.....	.....	....
∠	............and..	.....	.....	....
Z	△ At sea to Astronomical △ Port Mulgrave	232	15	38. 85
d Z	....	+ 2	06	45. 97
180°	....	.....	.....	....
Z′	Astronomical △ Port Mulgrave to △ At sea	54	22	24. 82

	°	′	″			°	′	″
L	58	37	00. 000	△ At sea...	M	142	14	01. 000
d L	......	+56	42. 000	176030^m. 1..............................	d M	- 2	27	45. 100
L′	59	33	42. 000	Astronomical △ Port Mulgrave	M′	139	46	15. 900

λ = 59° 05′ 21″		B	8. 5095133	C	1. 617450	D	2. 33720
		K cos Z	5. 0323869*n*	K² sin² Z	0. 287313	*h*²	7. 08378
1st term.	−3482″. 573	*h*	3. 5419002*n*	....	1. 904763	....	9. 42098
2d and 3d terms.	+ 80 . 573				80. 309	....	0. 264
−d L	−3402 . 000			sin Z	9. 8980693*n*	cos Z	9. 7867999*n*
				K sin Z	5. 1436563*n*	K cos Z	5. 0323869*n*
				K	5. 2455870	K	5. 2455870

Z	232° 15′ 38″. 85	......	....
tg Z	0. 1112694	......	....
K cos Z	5. 0323869*n*	......	....
K sin Z	5. 1436563*n*	......	....
A′	8. 5087016	d M	3. 9476836*n*
cos L′ ar. comp.	0. 2953257	sin λ	9. 9334710
	3. 9476836*n*	......	3. 8811546*n*
d M	— 8865″. 1	− d Z	— 7605″. 97

Determination of position of Mount Saint Elias.

		°	′	″
Z	Astronomical △ Port Mulgrave to Magnetic Mark	+133	24	57.5
∠	Magnetic Mark and Mount Saint Elias	+ 8	52	20
Z	Astronomical △ Port Mulgrave to Mount Saint Elias	+142	17	17.5
d Z	....	1	03	59.7
180°	....	.....	......	....
Z′	Mount Saint Elias to Astronomical △ Port Mulgrave	321	13	17.8

	°	′	″			°	′	″
L	59	33	42.000	Astronomical △ Port Mulgrave	M	139	46	15.9
d L	......	+ 47	03.280	111212^{m}.1	d M	+ 1	13	55.790
L′	60	20	45.280	Mount Saint Elias	M′	141	00	11.690

$\lambda = 59° 57' 13''.6$		K	5.0461520	K²	0.092304	....	....
		B	8.5094498	C	1.633619	D	2.32958
		cos Z	9.8982300*n*	sin² Z	9.573063	*h*²	6.90766
1st term.	−2843″.350	*h*	3.4538318*n*		1.298986		9.23724
2d and 3d terms.	+ 20 .079				19.906		.173
− d L	−2823 .280						

K	5.0461520	....	....
sin Z	9.7865314	....	....
A′	8.5086844	d M	3.6469710
cos L′ ar. comp.	0.3056032	sin λ	9.9373275
	3.6469710		3.5842985
d M	+ 4435″.790	− d Z	+ 3839″.71

Computation of distance from Mount Saint Elias to "Off Lituya Bay."

		°	′	″
Z	..............to..............	......	......	......
∠	..............and..............	......	......	......
Z	Mount Saint Elias to "Off Lituya Bay"............	314	47	50.90
d Z	....	+ 2	50	08.63
180°	....	......	......	......
Z′	"Off Lituya Bay" to Mount Saint Elias............	137	37	59.53

	°	′	″			°	′	″
L	60	20	45.280	Mount Saint Elias............	M	141	00	11.690
d L	− 1	45	5.280	269747m.14............	d M	− 3	17	31.690
L′	58	35	40.000	"Off Lituya Bay"............	M′	137	42	40.000

λ = 59° 28′ 12″.6		B	8.5093982	C	1.647264	D	2.32280
		K cos Z	5.2789013	K² sin² Z	0.563943	h²	7.57660
1st term.	+6141″.855	h	3.7882995	....	2.211207	....	9.89940
2d and 3d terms.	+ 163 .425				162.632	....	0.793
−d L	+6305 .280						
				sin Z	9.8510147n	cos Z	9.8479444
				K sin Z	5.2819716n	K cos Z	5.2789013
				K	5.4309569	K	5.4309569

Z	− 45° 12′ 09″.10	....	....
tg Z	0.0030703n	....	....
K cos Z	5.2789013	....	....
K sin Z	5.2819716n	....	....
A′	8.5087233	d M	4.0737802n
cos L′	0.2830853	sin λ	9.9351871
ar. comp.			
	4.0737802n	....	4.0029673n
d M	−11851″.690	−d Z	−10208″.63

Computation of distance from Mount Saint Elias to "Off Dry Bay."

		°	′	″
Z	............to..	......	......	......
∠	............and..	......	......	......
Z	Mount Saint Elias to "Off Dry Bay"	313	34	23.06
d Z	....	+ 2	18	56.96
180°	....	......	......	......
Z′	"Off Dry Bay" to Mount Saint Elias..............................	135	53	20.02

	°	′	″			°	′	″
L	60	20	45.280	Mount Saint Elias	M	141	00	11.690
d L	− 1	20	46.280	212819m.2..............................	d M	− 2	40	58.690
L′	58	59	59.000	"Off Dry Bay"	M′	138	19	13.000

λ = 59° 40′ 22″.1		B	8.5093982	C	1.647264	D	2.32280
		K cos Z	5.1664060	K²sin²Z	0.376094	h²	7.35161
1st term.	+4740″.282	h	3.6758042	....	2.023358	....	9.67441
2d and 3d terms.	+ 105 .998				105.526	....	0.472
−d L	+4846 .280						
				sin Z	9.8600359n	cos Z	9.8383952
				K sin Z	5.1880468n	K cos Z	5.1664060
				K	5.3280109	K	5.3280108

Z	−46° 25′ 36″.94	....	....
tg Z	0.0216408n	....	....
K cos Z	5.1664060	....	....
K sin Z	5.1880468n	....	....
A′	8.5087142	d M	3.9849182n
cos L′ ar. comp.	0.2881572	sin λ	9.9360893
	3.9849182n	....	3.9210075n
d M	−9658″.690	−d Z	−8336″.96

Note on Malaspina's Observations on Mount St. Elias.—A copy of Espinosa's "Memorias," &c. (1809), having part of the data used by Malaspina, has come to hand since this memoir was first published, and enabled us to recompute on his basis the height of Mount St. Elias. Though working with approximate formulæ and the imperfect instruments of the time, he appears to have been well qualified for his task. In brief, his position for Port Mulgrave was 59° 34′ 20″ north latitude, and 139° 42′ 12″ west longitude from Greenwich, according to his own determination. From his point of observation the mountain bore north 38° 50′ west, and by angles from a base-line he determined its distance as 55.1 nautical miles. His vertical angle for the peak was 2° 38′ 06″; being 05″ greater than that measured by the United States Coast Survey, a rather remarkable agreement. A computation by Coast Survey methods from his data gives a height of 17,664 feet, his own approximate calculation being 17,860 feet. The doubt lies wholly with his distance. We do not know exactly where his astronomical station was situated. His results would point to a position somewhat north and east of the United States Coast Survey station, but in any case the distance between either his or our own astronomical station and the mountain would be nearly the same. We do not know the length of his base nor how it was measured; we only know that the nature of the country would not admit of a measured base of more than a mile in length, if even so long. His angle of intersection at the mountain, under the most favorable hypothesis, could not exceed 3° 07′, introducing a considerable uncertainty into the distance as compared with the angle of about 60° obtained by us. Computed with the Coast Survey distance and Malaspina's data (except for distance) the height obtained is 19,473 feet, against 19,464 from our own observations. It is probable that a final elimination of all uncertainties at some future time will result in a height not greatly varying from 19,000 feet. W. H. D., February, 1878.

Computation of height of Mount Saint Elias.

Set.	Off Lituya Bay.	Off Dry Bay.	At sea, May 27.
	1	2	3
ζ	89° 50′ 54″. 9	89° 09′ 51″. 9	89° 12′ 26″. 0
log s	5. 4309569	5. 3280108	5. 3112625
log cot ζ	7. 4220521	8. 1638979	8. 1410566
log 1st term	2. 8530090	3. 4919087	3. 4523191
log $\frac{1}{2}$ $(1-2m)$ = log .42	9. 623249	9. 623249	9. 623249
log s^2	0. 861914	0. 656022	0. 622525
a. c. log ρ	3. 194587	3. 194563	3. 194885
log 2d term	3. 679750	3. 473834	3. 440659
log $(1-m)$ = log .92	9. 963788	9. 963788	9. 963788
log [1st term]^2	5. 706018	6. 983817	6. 904638
a. c. log ρ	3. 194587	3. 194563	3. 194885
log 3d term	8. 864393	0. 142168	0. 063311
1st term	712. 86	3103. 91	2833. 47
2d term	4783. 55	2977. 38	2758. 41
3d term	. 07	1. 39	1. 16
h	5496. 48	6082. 68	5593. 04
log h	3. 7400846	3. 7840950	3. 7476479
constant	0. 5159929	0. 5159929	0. 5159929
log h in feet	4. 2560775	4. 3000879	4. 2636408
h in feet	18033.	19956.	18350.

Set.	Astronomical Δ Port Mulgrave.
	4
ζ	87° 21′ 59″. 0
log s	5. 0461520
log cot ζ	8. 6627350
log 1st term	3. 7088870
log $\frac{1}{2}$ $(1-2m)$ = log .42	9. 623249
log s^2	0. 092304
a. c. log ρ	3. 194660
log 2d term	2. 910213
log $(1-m)$ = log .92	9. 963788
log [1st term]^2	7. 417774
a. c. log ρ	3. 194660
log 3d term	0. 576222
1st term	5115. 49
2d term	813. 23
3d term	3. 77
h	5932. 49
log h	3. 7732370
constant	0. 5159929
log h in feet	4. 2892299
h in feet	19464.

Set 1. Mean of nine altitudes from sea-horizon with Troughton sextant, No. 95, in adjustment.
Set 2. Mean of six altitudes from sea-horizon with Troughton sextant, No. 95, in adjustment.
Set 3. Mean of eight altitudes from sea-horizon with Troughton sextant, No. 95, in adjustment.
Set 4. Mean of eighteen double-zenith distances with Gambey vertical-circle, No. 75, in adjustment and level.

Computation of distance from Astronomical △ Port Mulgrave to Mount Cook.

		°	′	″
Z	................to	......	......	....
∠	................and	......	......	....
Z	Astronomical △ Port Mulgrave to Mount Cook........................	170	36	57.91
d Z	....	......	−11	53.01
180°	....	......	......	....
Z′	Mount Cook to Astronomical △ Port Mulgrave	350	25	04.90

	°	′	″			°	′	″
L	59	33	42.000	Astronomical △ Port Mulgrave	M	139	46	15.9
d L	......	+41	18.000	77740m.4	d M	......	+13	44.1
L′	60	15	00.000	Mount Cook................................	M′	140	00	00.0

λ = 59° 54′ 21″		B	8.5094498	C	1.633619	D	2.32958
		K cos Z	4.8847955n	K² sin² Z	8.205929	h^2	6.78849
1st term.	− 2478″.822	h	3.3942453n	....	9.839548	....	9.11807
2d and 3d terms.	+ .822				0.691	....	.131
−d L	− 2478 .000						
				sin Z	9.2123180	cos Z	9.9941491n
				K sin Z	4.1029646	K cos Z	4.8847955n
				K	4.8906466	K	4.8906464

Z	9° 23′ 02″.09	......	....
tg Z	9.2181691n	......	....
K cos Z	4.8847955n	......	....
K sin Z	4.1029646	......	....
A′	8.5086865	d M	2.915980
cos L′ ar. comp.	0.3043288	sin λ	9.937118
	2.9159799	.....	2.853098
d M	+ 924″.1	−d Z	+713″.01

Computation of distance from Astronomical △ Port Mulgrave to Mount Vancouver.

		°	′	″
Z	............to..............................	......	......	....
∠	............and..............................	......	......	....
Z	Astronomical Δ Port Mulgrave to Mount Vancouver	182	19	36. 66
d Z	....	......	+ 2	49. 47
180°	....	......	......	....
Z′	Mount Vancouver to Astronomical Δ Port Mulgrave	2	22	26. 13

	°	′	″			°	′	″
L	59	33	42. 000	Astronomical Δ Port Mulgrave	M	139	46	15. 900
d L	......	+39	58. 000	74265ᵐ.5..................................	d M	......	− 3	15. 900
L′	60	13	40. 000	Mount Vancouver	M′	139	43	00. 000

$\lambda = 59° 53' 41''$		B	8. 5094498	C	1. 633619	D	2. 32858
		K cos Z	4. 8704287*n*	K² sin² Z	6. 958626	*h*²	6. 75976
1st term.	−2398″. 162	*h*	3. 3798785*n*	....	8. 592245	....	9. 08934
2d and 3d terms.	+ . 162				. 0391	....	. 1228
−*d* L	−2398 . 000						
				sin Z	8. 6085263*n*	cos Z	9. 9996418*n*
				K sin Z	3. 4793132*n*	K cos Z	4. 8704287*n*
				K	4. 8707869	K	4. 8707869

Z	2° 19′ 36″. 66	....	....
tg Z	8. 6088845	....	....
K cos Z	4. 8704287*n*	....	....
K sin Z	3. 4793132*n*	....	....
A′	8. 5086870	*d* M	2. 2920344*n*
cos L′ ar. comp.	0. 3040342	sin λ	9. 9370689
	2. 2920344*n*	....	2. 2291033*n*
d M	−195″. 9	−*d* Z	−169″. 47

Computation of heights of Mounts Cook and Vancouver.

Set.	Mount Cook.	Mount Vancouver.
	1	2
ζ	86° 40′ 11″. 6	87° 10′ 20″. 2
log s	4. 8906466	4. 8707869
log cot ζ	8. 7648255	8. 6936669
log 1st term	3. 6554721	3. 5644538
log $\frac{1}{2}$ $(1-2m)$ = log . 42	9. 623249	9. 623249
log s^2	9. 781293	9. 741574
a. c. log ρ	3. 194922	3. 194940
log 2d term	2. 599464	2. 559763
log $(1-m)$ = log .92	9. 963788	9. 963788
log [1st term]^2	7. 310944	7. 128908
a. c. log ρ	3. 194922	3. 194940
log 3d term	0. 469654	0. 28[illegible]536
1st term	4523. 47	3668. 21
2d term	397. 62	362. 88
3d term	2. 95	1. 94
h	4924. 04	4033. 03
log h	3. 6923216	3. 6056314
constant	0. 5159929	0. 5159929
log h in feet	4. 2083145	4. 1216243
h in feet	16155.	13232.

Set 1. Mean of four double-zenith distances with Gambey vertical-circle, No. 75, adjusted and leveled.
Set 2. Mean of six double-zenith distances with Gambey vertical-circle, No. 75, adjusted and leveled.

APPENDIX No. 14.

REPORT CONCERNING RECENT OBSERVATIONS AT SOUTH PASS BAR, MISSISSIPPI RIVER, BY HENRY MITCHELL, ASSISTANT IN THE UNITED STATES COAST SURVEY.

BOSTON, *March* 10, 1875.

The original programme for this work contemplated the determination of transverse and vertical curves of velocity, from point to point, along the course of each pass and out over the bars to the sea. These observations were to be, as far as practicable, simultaneous from section to section, and were to be repeated at different periods of the tide. Among other questions we hoped to answer by this course of inquiry were the following:

1st. In what manner does the outflowing stream expand as it approaches the sea, and how is this expansion related to depth and velocity?

2d. How does the meeting of fresh and sea water densities affect the channel depth, or how are these related?

3d. Is there any indication of a littoral current beyond the bar?

The observations at the mouth of the South Pass have been made somewhat in accord with the pre-arranged plan, and appear to have been made under favorable conditions; but they are few in number, so that our conclusions are by no means final. Mr. Marindin, the assistant of the Coast Survey having immediate charge of the party, and Mr. Weir, his principal observer, as well as several other members of the party, were familiar with our methods, having had long previous experience elsewhere.

I, therefore, have full confidence in the work done, although I left the locality before the party were fully engaged. I shall refer to the statistics of the work hereafter in some detail.

§ 1. EXPANSION.—As the stream approaches the sea after passing the contraction in the neighborhood of the South Pass light-house, it expands at the expense both of its depth and velocity. The banks, on both sides below the light-house, are covered with thick growth of reeds which extend much further seaward upon the right than upon the left shore. If we view the scene at high water, we find the right bank exposed to view for a distance of 9,420 feet below the light-house, while the left bank is visible only to a distance of 1,987 feet below a point opposite the light-house. But at extreme low water the flats are exposed quite out to the bar and the two banks are seen to be essentially of the same length. At the time of our observations the low banks above referred to were mostly submerged and there seems to have been some escape of the water over them. In a distance of 8,000 feet below the light-house the river increases its superficial width five-fold, *i. e.*, from 712 feet at section A (see sketch No. 24) to 3,400 feet at section B. Section A represents the pass just within its visible mouth, and section B the outlet-channel just within the crest of the bar. The areas of these sections show an increase of 36 per cent., *i. e.*, from 18,270 square feet at A to 24,600 square feet at B. The mean depth has diminished from 24.44 feet at A to 8.03 feet at B, or in much less ratio than the width has increased.

As the velocity (mean) should vary inversely as the section, and as the depth (representing scour) should vary as the squares of the velocity, we should expect, under ordinary circumstances, that the depths should be inversely as the squares of the sections. But from the figures above you will observe that the depths from section A to section B vary as 3 is to 1, while the squares of the sections vary as 2 is to 1. We might argue from this that some *lifting* force has been at work—the denser water of the sea, for instance—and thus discover in our results a confirmation of the statement upon page 445 of the Physics and Hydraulics of the Mississippi River, that "this lifting force of the salt-water must widen the river-current." But from the best reductions we can make of the velocities in the two sections which were not occupied by current-stations simultaneously, except for the axis of the stream, the mean velocities were 1.30 feet per second against 0.66, giving for the ratios of their squares 3.65 to 1, which is not widely different from the ratio of mean depths.

Again, if we compare the vertical curves of velocity *simultaneously* observed in the thread of the stream for both sections, we find the axial scour at $(1.71)^2 : (1.09)^2 = 2.46 : 1$, and the channel-depths to which they correspond $29 : 11.5 = 2.52 : 1$, from which I think we must conclude that as far as our evidence may cover the case, the depths vary with the squares of the velocity, leaving no room for the interference of any other element. And our curves of specific gravity taken at the same time indicate only a slight intrusion of sea-water at the seaward section B. When it is considered that our observations were made at the low stage of the river, it will be admitted that for the permanent order of things our sections must be regarded as those of *fresh-water conduits*, and since the levels alter but little, from low stages to flood, we may conclude that the axial velocities will preserve much the same ratios.

Thus far I am inclined to regard the expansion of the stream as *primary* and the loss of depth *dependent*. This granted, the increase of sectional area is seen to be a necessity growing out of the increase of wetted perimeter, which reduces the velocity by friction.

At other periods of the tide than that at which we observed the sections, brackish water was found higher up the stream, but to no great extent.

§ 2. I submit that the exclusion of the sea-water from the South Pass at the time of our observations was due mainly to the presence of the bar as an antecedent obstruction. The velocity of the outflow at the light-house corresponded to a fall in space of 0.03 foot, and the elevation of the actual river surface above the sea could not have been measured, probably, because so small. The dynamic pressure due to the impulse of the issuing stream cannot exceed twice the weight of the *head due* to velocity; so that a stratum of sea-water having a thickness of 7 feet (the depth on the crest of the bar) would by its greater specific weight have very much overbalanced the river as it flowed through the light-house section. One may easily see that if at the time of our observations the bar had been taken away, the sea-water would have poured in along the bed of the pass with a velocity near the bottom very much greater than that of the surface outflow observed. We must conclude, then, it seems to me, that the bar had been built by floods when the river was issuing at a higher velocity and at a *higher surface elevation*, so that it overmastered the sea, and that the office which the bar filled in the low-river season, when we made our observations, was that of a bulwark holding back the sea.

We may expect that so long as the proposed jetties serve to dissipate the bar there will be an influx of the sea during the low-river season, and some tendency to fill up the pass, but the material brought in must be small; and since the surface fresh-water velocity must be increased at some stages of the tide, and will be scarcely diminished at any other stages, deposits of much sediment need not be anticipated.

I call your attention to the vertical curves of specific weights given in our table and sketch, and also to the diagram (sketch 24) showing a "section of South Pass along the channel-way." Our observations made shortly after low tide probably give the minimum of sea-water for the day.

§ 3. At the same time that the transverse curve of velocities was being determined at section B, another transverse curve was being determined just outside the bar. This outer curve depends upon three stations, and unfortunately the maximum velocity falls upon the most western instead of upon the central station (as was designed); in other words, our curve is too far to the eastward, so that its apex does not fall in the middle, leaving some doubt whether the position of the thread of the stream was reached.

Nevertheless, for the purposes in view these three stations are highly important, since they reveal the presence of a current in excess of the discharge from the South Pass. Assuming that the section in motion is limited by our extreme stations—which, of course, it is not—we find the passing volume nearly 107,596 cubic feet per second, or over four times the discharge given by our corrected curve at section A, off the light-house in the South Pass, and over five times the volume passing over the bar as given by the *simultaneous* observations at section B. At this outermost section the depth is not only greater in the average from side to side than at the sections above, but the average velocity from surface to bottom is some 30 per cent. greater than at the light-house section, and the maximum velocity of the 6-feet-surface stratum is double that found at the section just within the bar. Moreover, a change in the direction of the current is observed

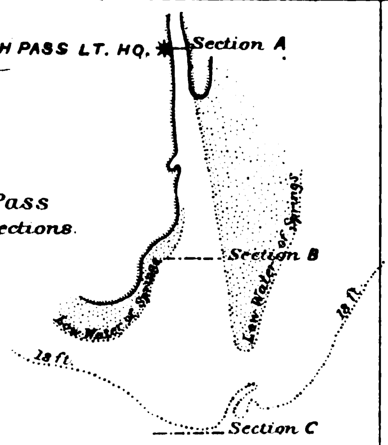


Fig. 1.
Mouth of South Pass
showing Positions of Sections.

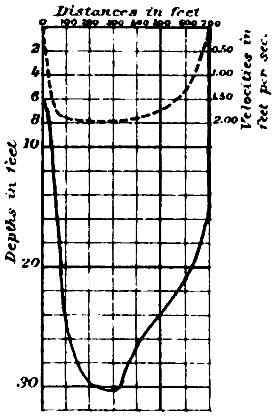


Fig. 2.
Section A

In Figs. 2 & 3, full lines show profiles of channel bed;
Dotted lines show transverse curves of velocity.

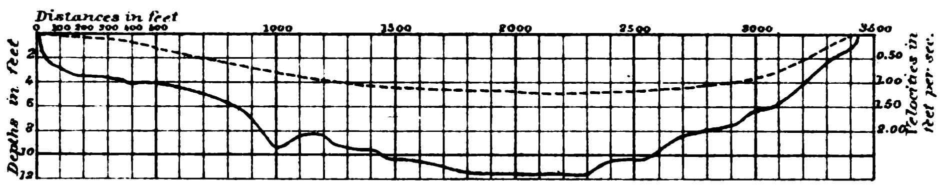
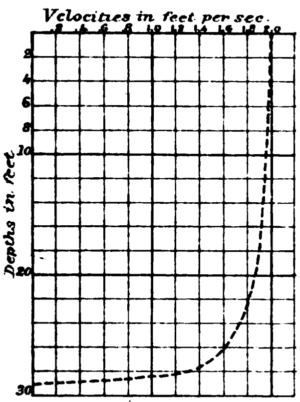
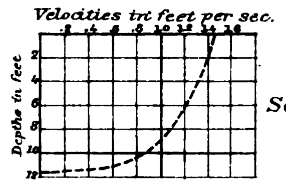


Fig. 3.
Section B



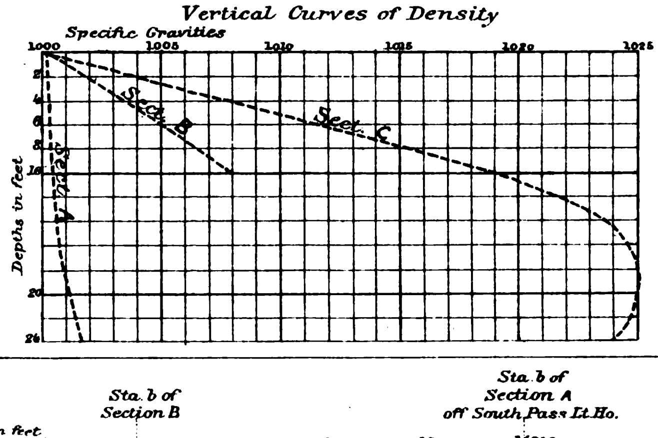
Section A

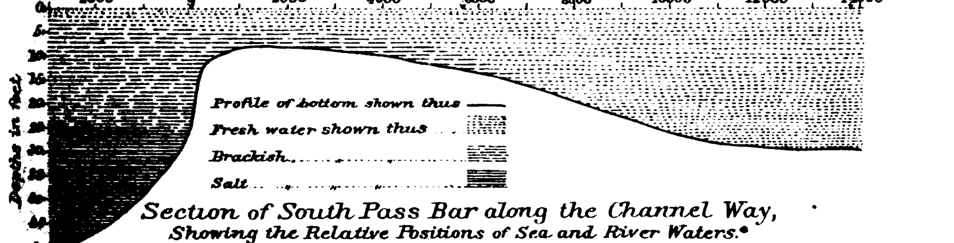
Vertical curves of velocity at central stations.



Section B

Vertical Curves of Density





Section of South Pass Bar along the Channel Way,
Showing the Relative Positions of Sea and River Waters.
Jan'y 30, 1875.

deflecting to the westward; so that no doubt exists in our minds that at the time of our observations there was a strong littoral current, or *race of the sea*, along the outer slope of the South Pass bar.

In our sketch, (No. 24,) which accompanies this report, we have not given the "outer" curve of velocities above mentioned, because it was incomplete, as we have stated, and because it was not *transverse*—the currents being deflected from their anticipated course. The weather at the time of these observations was quiet; the wind, being light from north and northeast, could not have had any measurable influence, but for several days previous the weather had been windy, and considerable sea was running on the day of the observations.

The water issued from the South Pass in a southeasterly direction, but after crossing the bar was turned to the southward and southwestward. At one of the outside stations occupied on the same day but at a different hour from those which formed our curve, the observer, Mr. Weir, made a special note in his record to the effect that the submerged floats moved to the westward, while the line upon the surface was carried southward.

Whether this movement along the outer slope of the bar is a *race* of the sea or a littoral current, we have not enough data to determine; suffice it to say, we found it steady at the depth of 24 feet, and have no adequate reason for supposing that it was the result of anomalous or unusual circumstances.

South Pass bar is not salient to the general sweep of the delta frontage. I called attention last year to the fact that a circle could be drawn which would pass through four of the bars, viz: Southwest Pass, South Pass, Southeast Pass, and Pass à Loutre, and fall only 2,300 feet within a fifth bar—that of Northeast Pass. This circle has a radius of 21½ statute miles, and its center lies about 2½ miles to the southward of the Jump, in latitude 29° 14′ 20″, longitude 89° 20′ 15″, and 8¼ miles above the head of the passes, as found upon the printed chart of the Coast Survey.

Nevertheless, the South Pass bar lies nearer to those deep contours of the Gulf, which seem not yet to have been reached by the aproning of the delta, than any of the others, and must therefore be regarded as *the salient point of the delta* as regards the Gulf and its movements. This is among the reasons why the experiment of jetties at this pass seems to me more likely to be successful than at the others, and within a reasonable cost.

The new deposits, after the jetties are built, are likely to be swept away to some extent by the coast-current and the *race* of the sea. It does not compare favorably with the two other passes in width, depth, and previous good character, as regards freedom from obstructions.

Respectfully submitted.

(Signed) HENRY MITCHELL,
United States Coast Survey.

CARLILE P. PATTERSON,
Superintendent United States Coast Survey.

The tables which follow have been computed from three determined points in the horizontal and vertical.

Specific weights of water—Mouth of South Pass.

Depths in feet.	Specific weights in thousands.	Remarks.
0	1. 0000	
6	1. 0110	
12	1. 0215	Middle station at section C, outside of bar.
18	1. 0250	
24	1. 02[illegible]0	
0	1. 0002	
6	1. 0050	Middle station at section B, on inner slope of bar.
10	1. 0080	
0	1. 0003	
12	1. 0005	Middle station at section A, off light-house.
24	1. 0015	

SECTION A.

South Pass of Mississippi River at light-house.

Distance from right bank in feet.	Velocity in feet per second for stratum from 0 to 6 feet.	Velocity in feet per second for stratum from 6 to 12 feet.	Velocity in feet per second for stratum from 12 to 18 feet.	Velocity in feet per second for stratum from 18 to 24 feet.	Velocity in feet per second for stratum from 24 to 29 feet.	Velocity in feet per second for stratum from 29 feet.
0	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00
100	1. 94	1. 98	1. 86	1. 77	0. 00	0. 00
200	1. 94	1. 96	1. 89	1. 83	0. 97	0. 00
300	1. 96	1. 94	1. 89	1. 84	1. 15	0. 34
400	1. 96	1. 93	1. 88	1. 74	0. 39	0. 00
500	1. 77	1. 81	1. 54	1. 30	0. 00	0. 00
600	1. 37	1. 43	0. 93	0. 00	0. 00	0. 00
700	0. 20	0. 17	0. 08	0. 00	0. 00	0. 00
712	0. 00	0. 00	0. 00	0. 00	0. 00	0. 00
Mean velocity in feet per second	1. 38	1. 38	1. 40	1. 47	0. 76	0. 34
Area of stratum in square feet	4272	4272	4176	3264	1420	116
Volume passing in cubic feet per second	5893	5893	5846	4798	1079	38

Total volume passing per second = 23,547 cubic feet.

SECTION B.

South Pass Mississippi River, on the inner slope of the bar.

Distance from right bank in feet.	Velocity from surface to depth of 6 feet, feet per second.	Soundings, feet.	Volume passing through upper stratum, cubic feet.	Velocity below 6 feet from surface.	Volume passing through lower stratum.
0	0. 00	2. 0	....	....	....
300	0. 17	3. 5	70	....	....
600	0. 36	4. 5	318	....	....
900	0. 71	7. 0	923	....	....
1200	0. 90	8. 5	1449	0. 31	81
1500	1. 09	10. 5	1791	0. 54	446
1800	1. 21	11. 5	2070	0. 65	893
2100	1. 21	11. 5	7178	0. 61	1039
2400	1. 23	10. 5	2208	0. 46	802
2700	1. 23	8. 5	2214	0. 25	373
3000	1. 01	6. 5	2016	0. 03	63
3300	0. 34	2. 5	911	....	....
3425	0. 00	1. 5	102	....	....
Sums ...	....	....	16250	....	3697

Total volume passing through section = 19,947 cubic feet per second.

SECTION C.

Outside of South Pass Bar, January 30, 1875.

Distance from first station.	Velocity in feet per second.						Remarks.
	0 to 6 feet.	Stratum 6 to 12 feet.	Stratum 12 to 18 feet.	Stratum 18 to 24 feet.	Stratum 24 to 30 feet.	Strata below 30 feet.	
0.........................	2. 4	2. 2	2. 1	2. 0	1. 5	....	The section lies across the stream just seaward of South Pass bar, *i. e.*, upon fore slope of said bar. The blanks are left when the depths fall off.
500.........................	2. 2	2. 1	2. 0	2. 0	1. 5	0. 6	
1000.........................	2. 1	1. 9	1. 8	1. 8	1. 4	0. 6	
1500.........................	1. 9	1. 7	1. 6	1. 7	....	....	
2000.........................	1. 7	1. 7	1. 6	1. 3	0. 4	....	
2224.........................	1. 6	1. 7	1. 6	1. 2	0. 7	....	
Means	2. 0	1. 9	1. 8	1. 8	1. 3	0. 6	
Sectional areas of strata	13344	13344	13344	13344	1974	8250	
Passing volumes in cubic feet	26688	25354	24019	24019	2566	4950	

Total volume passing per second 107,596 cubic feet.

APPENDIX No. 12.

DISCUSSION OF TIDES IN NEW YORK HARBOR.

UNITED STATES COAST SURVEY OFFICE,
Washington, June 30, 1875.

DEAR SIR: I have the honor to submit the following report of the discussion of the tidal observations of Governor's Island in New York Harbor.

1. The observations used embrace a series of 19 years, from 1856 to 1874, inclusive. There are some interruptions in the continuity of the series, especially in the first part of it, arising from the freezing-up of the tide-gauge and from storms; but these are mostly of short duration, and do not seriously impair the value of the observations, or affect sensibly the accuracy of the results deduced from them.

In this discussion, the first reductions of the observations made by the Coast Survey were furnished to me for the purpose. These comprise the times and heights of the high and low waters of the tide, together with the apparent times of the moon's meridian transit immediately preceding the times of high water, and the corresponding lunitidal intervals.

THE GENERAL PLAN AND IMMEDIATE OBJECT OF THE DISCUSSION.

2. The general plan adopted in this discussion is the same as that of the discussion of the tidal observations of Boston Harbor, the deviations being merely in some of the details. This plan is found to work well and give very accurate results. It is not claimed, however, that, by methods involving a much greater amount of labor, a slight improvement in the accuracy of the results might not have been obtained. By the method used, the probable error in the mean amplitude of the tide, or in the co-efficient of any of its inequalities, depending upon abnormal disturbances, errors of observations, and imperfections in the methods of reductions and of the discussion, is not more than one-twentieth of an inch, and, in the case of the lunitidal interval, not more than one-quarter of a minute. Of course, errors of these orders are of no consequence in any practical applications of the results; and even in the nicest comparisons between theoretical relations and those deduced in the discussion of the observations, these errors are so much smaller than those of any tidal theory which we now have, or can ever hope to have, that it would hardly seem to be worth while to expend a great amount of additional labor in order to diminish very slightly these small probable errors.

3. The immediate object of the discussion of the observations is the determination of the mean amplitude and lunitidal interval of the tide, and the co-efficients and epochs of their principal inequalities, and the first step in the plan adopted consists in grouping all the observations of the lunitidal intervals and of the heights of high and low waters with reference to the arguments of the inequalities taken two and two, so that each group shall give the averages of the observations within certain small ranges of each one of these two arguments; as, for instance, the twenty-fourth part of the arguments corresponding to the periods of the inequalities. From these averages, the effects of all abnormal disturbances of the winds and of barometric pressure, and also the other *normal* inequalities, are very nearly eliminated, since in both the plus and minus effects must very nearly counteract each other, and we have simply the averages as affected for the most part by the two inequalities merely sought to be determined. The averages of these groups being entered into tables with double arguments, and being summed each way, we get other averages, affected by only one of the inequalities. This method shortens very much the amount of work, since the observations can be grouped with reference to two arguments in very nearly the same time that they could

with reference to one simply; and thus, when we have obtained the averages as affected by one inequality, it requires but little additional labor to sum the averages of the groups, and obtain averages affected only by the other inequality; and we thus save the trouble of grouping all the observations again with reference to the argument of the second inequality. When the averages have been obtained, affected only by the inequalities having the same argument, by comparing these averages with their known form of expression, we can make out as many equations of condition as we have averages, for determining the unknown amplitudes and epochs of the inequalities, as will be explained as we proceed.

ADOPTED NOTATIONS.

4. The notation of the arguments adopted in this discussion is the same as that used in the development of the tidal forces in § 19 of *Tidal Researches*, published as an appendix to the Coast Survey Report for 1874; and that of the lunitidal intervals and heights of high and low water is the same as that adopted in various parts of those *Researches*. The notation is as follows:—

φ_1 = the angular distance between the moon and sun, expressed either in arc or in time, being, in the latter case, denoted by the apparent time of the moon's meridian transit;
φ_2 = the moon's mean anomaly;
$\varphi_3 = 2\lambda$, in which λ is the moon's longitude;
φ_4 = the longitude of the moon's ascending node;
φ_6 = the sun's true anomaly;
φ^7 = the sun's true longitude;
$\varphi_{11} = 2\,\varphi_1$;
$\varphi_{12} = 2\,\varphi_2$.

The other arguments not given here belong to very small inequalities, which we have not attempted to determine in this discussion, and which consequently we have had no occasion to use.

We also put—

H_1, λ_1 = the height of the first high water after the moon's upper transit, and the corresponding lunitidal interval, respectively;
H_2, λ_2 = the same for the following low water;
H_3, λ_3 = the height of the high water next following the moon's lower transit, and the corresponding lunitidal interval;
H_4, λ_4 = the same for the following low water.

We shall also put for convenience—

$$H'_1 = \tfrac{1}{2}(H_1 + H_3) \qquad \lambda'_1 = \tfrac{1}{2}(\lambda_1 + \lambda_3)$$
$$H'_2 = \tfrac{1}{2}(H_2 + H_4) \qquad \lambda'_2 = \tfrac{1}{2}(\lambda_2 + \lambda_4)$$
$$A_2 = \tfrac{1}{2}(H'_1 - H'_2) \qquad L_2 = \tfrac{1}{2}(\lambda'_1 + \lambda'_2)$$
$$H_0 = \tfrac{1}{2}(H'_1 + H'_2)$$

AVERAGES DEDUCED DIRECTLY FROM THE OBSERVATIONS.

5. With the preceding explanations of the notations used, together with the additional explanations following, the following tables of averages will be understood.

TABLE I.

Containing average values belonging to the argument φ_1.

Obs.	ϕ_1		λ'_1		λ'_2		H'_1	H'_2	L_2		A_2	H_0	δH_0	$\lambda'_2-\lambda'_1$	
	h.	m.	h.	m.	h.	m.	Feet.	Feet.	h.	m.	Feet.	Feet.	Feet.	h.	m.
560	0	15.1	8	12.2	14	50.0	9.008	3.657	11	31.1	2.675	6.332	+ .015	6	37.8
525	0	44.5	8	8.5	14	42.4	9.001	3.711	11	25.4	2.645	6.356	+ .039	6	33.9
544	1	14.6	8	3.1	14	38.8	8.895	3.638	11	21.0	2.628	6.266	— .051	6	35.7
545	1	44.5	8	0.2	14	29.9	8.862	3.732	11	15.0	2.565	6.297	.020	6	29.7
555	2	14.8	7	58.2	14	23.9	8.789	3.838	11	11.1	2.475	6.313	.004	6	25.7
535	2	44.5	7	56.1	14	16.1	8.686	3.940	11	6.1	2.373	6.313	.004	6	20.0
558	3	14.8	7	57.3	14	11.4	8.564	4.023	11	4.3	2.270	6.293	— .024	6	14.1
533	3	44.3	7	52.5	14	8.7	8.507	4.250	11	0.6	2.128	6.378	+ .061	6	16.2
562	4	14.3	7	53.4	14	5.9	8.495	4.408	10	59.7	2.043	6.451	.134	6	12.5
540	4	44.3	7	51.3	14	7.6	8.413	4.502	10	59.4	1.955	6.457	.140	6	16.3
582	5	14.7	7	53.0	14	16.3	8.337	4.567	11	4.7	1.885	6.452	.135	6	23.3
549	5	44.6	7	52.7	14	28.0	8.253	4.590	11	10.4	1.831	6.421	.104	6	35.3
562	6	14.5	7	52.8	14	35.8	8.121	4.590	11	14.3	1.760	6.355	.038	6	43.0
559	6	44.4	7	57.0	14	46.2	8.168	4.605	11	21.6	1.781	6.386	+ .069	6	49.2
571	7	14.9	8	3.3	14	52.4	8.101	4.450	11	27.8	1.825	6.275	— .042	6	49.1
543	7	44.6	8	10.2	14	57.0	8.185	4.314	11	33.6	1.935	6.250	.067	6	46.8
565	8	14.6	8	18.9	15	0.7	8.072	4.236	11	39.8	1.918	6.154	.063	6	41.8
549	8	44.7	8	28.5	15	4.5	8.389	4.157	11	46.5	2.116	6.273	.044	6	36.0
552	9	14.9	8	29.6	15	3.9	8.407	3.973	11	46.7	2.217	6.190	.127	6	34.3
536	9	44.4	8	29.2	15	4.3	8.584	3.894	11	46.7	2.345	6.239	.078	6	35.1
549	10	14.4	8	26.3	15	2.9	8.728	3.821	11	44.6	2.453	6.274	.043	6	36.6
546	10	44.5	8	22.6	14	59.5	8.795	3.744	11	41.0	2.525	6.270	.047	6	36.9
555	11	15.0	8	20.2	14	57.6	8.863	3.718	11	38.9	2.572	6.290	— .027	6	37.4
525	11	44.8	8	15.7	14	53.0	8.946	3.717	11	34.4	2.614	6.331	+ .014	6	37.3
Means ..	....		8	7.2	14	39.9	8.550	4.088	11	23.5	2.231	6.317	... .	6	32.7

TABLE II.

Containing average values belonging to the argument φ_2.

Obs.	ϕ_2	λ'_1		λ'_2		H'_1	H'_2	L_2		A_2	H_0	δH_0	$\lambda'_2-\lambda'_1$	
	°	h.	m.	h.	m.	Feet.	Feet.	h.	m.	Feet.	Feet.	Feet.	h.	m.
549	15	7	57.7	14	41.5	9.054	3.704	11	19.6	2.675	6.379	+ .059	6	43.8
544	30	8	1.2	14	43.1	8.891	3.644	11	22.2	2.623	6.267	— .053	6	41.9
541	45	8	3.6	14	41.7	8.950	3.742	11	22.6	2.604	6.346	+ .026	6	38.1
543	60	8	6.1	14	43.8	8.845	3.810	11	25.0	2.517	6.327	+ .007	6	37.7
548	75	8	7.7	14	44.7	8.742	3.864	11	26.2	2.439	6.303	— .017	6	37.0
550	90	8	9.4	14	44.9	8.632	3.974	11	27.1	2.329	6.303	— .017	6	35.5
551	105	8	12.4	14	45.2	8.550	4.141	11	28.3	2.205	6.345	+ .025	6	32.8
551	120	8	14.2	14	44.0	8.423	4.181	11	29.1	2.121	6.302	— .018	6	29.8
559	135	8	16.1	14	42.3	8.353	4.255	11	29.2	2.049	6.304	— .016	6	26.2
540	150	8	18.4	14	40.5	8.290	4.372	11	29.4	2.959	6.331	+ .011	6	22.1
556	165	8	15.6	14	39.7	8.250	4.434	11	27.7	2.908	6.342	+ .022	6	24.1
544	180	8	15.9	14	42.9	8.231	4.390	11	29.4	2.920	6.310	— .010	6	27.0
548	195	8	15.2	14	38.8	8.195	4.520	11	27.0	2.837	6.357	+ .037	6	23.6
544	210	8	12.2	14	38.7	8.269	4.441	11	25.5	2.914	6.355	+ .035	6	26.5
549	225	8	10.7	14	38.8	8.194	4.411	11	24.7	2.891	6.302	— .018	6	28.1
548	240	8	8.6	14	34.4	8.264	4.354	11	21.5	2.955	6.309	.011	6	25.8
553	255	8	5.7	14	35.0	8.321	4.314	11	20.4	2.004	6.317	— .003	6	29.3
556	270	8	4.6	14	34.1	8.429	4.244	11	19.3	2.092	6.336	+ .016	6	29.5
548	285	8	3.7	14	33.4	8.520	4.121	11	18.6	2.200	6.320	.000	6	29.7
548	300	7	59.9	14	37.2	8.614	4.016	11	18.5	2.299	6.315	— .005	6	37.3
552	315	7	59.4	14	37.7	8.675	3.684	11	18.5	2.396	6.280	.040	6	38.3
548	330	7	57.5	14	35.7	8.776	3.793	11	16.6	2.442	6.284	.036	6	38.2
540	345	7	57.4	14	38.7	8.840	3.728	11	18.0	2.556	6.284	— .036	6	41.3
526	360	7	58.8	14	39.3	9.006	3.728	11	19.1	2.639	6.367	+ .047	6	40.5
Means ..	......	8	7.2	14	39.8	8.555	4.086	11	23.5	2.232	6.320	....	6	32.5

TABLE III.

Containing average values belonging to the argument φ_3.

λ	Obs.	λ_1		λ_2		H_1	H_2	Obs.	λ_3		λ_4		H_3	H_4
°		h.	m.	h.	m.	Feet.	Feet.		h.	m.	h.	m.	Feet.	Feet.
7.5	279	8	14.9	14	51.6	9.006	4.093	273	8	7.7	14	32.2	8.368	3.997
22.5	274	8	13.4	14	52.1	9.036	4.117	277	8	8.8	14	29.4	8.303	4.078
37.5	269	8	7.7	14	48.3	8.966	4.138	261	8	8.9	14	24.7	8.190	4.152
52.5	267	8	1.0	14	48.0	8.940	4.109	272	8	5.0	14	20.5	8.114	4.262
67.5	275	7	55.4	14	47.7	8.901	4.103	273	8	3.5	14	20.3	8.161	4.355
82.5	276	7	53.1	14	45.8	8.827	4.098	276	8	5.2	14	19.6	8.122	4.288
97.5	266	7	53.3	14	45.5	8.788	3.944	274	8	6.2	14	23.2	8.158	4.231
112.5	277	7	55.1	14	45.7	8.814	4.013	273	8	8.6	14	27.6	8.394	4.320
127.5	274	7	54.6	14	43.4	8.756	3.924	278	8	11.1	14	34.7	8.531	4.224
142.5	273	7	59.5	14	44.1	8.600	3.884	272	8	15.2	14	40.0	8.641	4.174
157.5	275	8	3.7	14	44.5	8.513	3.853	271	8	18.8	14	44.4	8.782	4.092
172.5	276	8	5.6	14	43.1	8.440	3.934	275	8	21.2	14	50.3	8.838	4.071
187.5	275	8	8.8	14	37.0	8.324	4.039	274	8	22.3	14	51.0	8.943	4.125
202.5	273	8	9.3	14	34.7	8.243	4.099	271	8	18.8	14	54.2	8.982	4.089
217.5	271	8	10.1	14	28.5	8.127	4.223	272	8	15.2	14	51.6	8.972	4.137
232.5	278	8	8.8	14	28.7	8.066	4.371	270	8	7.4	14	51.8	9.001	4.116
247.5	271	8	4.5	14	25.3	8.100	4.418	271	8	4.0	14	51.2	8.924	4.158
262.5	274	8	0.2	14	28.3	8.083	4.290	272	7	58.8	14	49.7	8.874	4.010
277.5	265	8	2.7	14	27.6	8.187	4.289	274	8	1.0	14	45.2	8.809	3.963
292.5	273	8	4.2	14	33.3	8.307	4.297	270	7	59.7	14	45.0	8.753	3.909
307.5	271	8	7.7	14	36.8	8.507	4.196	272	8	1.5	14	42.2	8.773	3.859
322.5	278	8	11.2	14	42.1	8.686	4.137	274	8	3.2	14	40.5	8.731	3.823
337.5	277	8	13.6	14	47.5	8.800	4.113	274	8	8.2	14	38.4	8.719	3.900
352.5	266	8	14.8	14	51.3	8.918	4.062	274	8	7.5	14	37.0	8.554	3.915
	Means ..	8	4.7	14	40.9	8.580	4.115	......	8	8.7	14	38.5	8.610	4.094

TABLE IV.

Containing average values belonging to the argument φ_3.

λ	Obs.	λ'_1		λ'_2		H'_1	H'_2	L_2		A_2	H_0	δH_0	$\lambda_2-\lambda_1$	
°		h.	m.	h.	m.	Feet.	Feet.	h.	m.	Feet.	Feet.	Feet.	h.	m.
7.5	552	8	11.3	14	41.9	8.687	4.045	11	26.6	2.321	6.366	+ .016	6	30.6
22.5	551	8	11.1	14	40.7	8.660	4.097	11	25.9	2.281	6.381	.031	6	29.6
37.5	530	8	8.3	14	36.5	8.578	4.145	11	22.4	2.217	6.361	.011	6	28.2
52.5	539	8	3.0	14	34.2	8.527	4.185	11	18.6	2.171	6.356	.006	6	31.2
67.5	548	7	59.4	14	34.0	8.531	4.229	11	16.7	2.151	6.380	+ .030	6	34.6
82.5	552	7	59.1	14	32.7	8.475	4.193	11	15.9	2.141	6.334	— .016	6	33.6
97.5	540	7	59.7	14	34.4	8.473	4.088	11	17.0	2.192	6.281	— .069	6	34.7
112.5	550	8	1.8	14	36.6	8.604	4.166	11	19.2	2.219	6.386	+ .036	6	34.8
127.5	552	8	2.8	14	39.0	8.643	4.074	11	20.9	2.285	6.359	+ .009	6	36.2
142.5	545	8	7.1	14	42.0	8.621	4.029	11	24.5	2.296	6.325	— .025	6	34.9
157.5	546	8	11.2	14	44.5	8.647	3.973	11	27.8	2.337	6.310	.040	6	33.3
172.5	551	8	13.4	14	46.7	8.639	4.002	11	30.0	2.318	6.320	— .030	6	33.3
187.5	549	8	15.5	14	44.0	8.634	4.082	11	29.7	2.276	6.358	+ .008	6	38.5
202.5	544	8	14.1	14	44.5	8.613	4.094	11	29.3	2.260	6.356	.006	6	30.4
217.5	543	8	12.6	14	40.0	8.550	4.180	11	26.3	2.185	6.365	.015	6	37.4
232.5	548	8	8.1	14	40.2	8.533	4.243	11	24.2	2.145	6.388	.038	6	32.1
247.5	542	8	4.3	14	38.3	8.512	4.288	11	21.3	2.112	6.400	+ .050	6	34.0
262.5	546	7	59.5	14	39.0	8.478	4.150	11	19.2	2.164	6.314	— .036	6	39.5
277.5	539	8	1.8	14	36.4	8.498	4.126	11	19.1	2.186	6.312	.038	6	34.6
292.5	543	8	2.0	14	39.1	8.530	4.103	11	20.5	2.213	6.316	.034	6	37.1
307.5	543	8	4.6	14	39.5	8.640	4.027	11	22.0	2.307	6.333	.017	6	34.9
322.5	552	8	7.2	14	41.3	8.708	4.980	11	24.2	2.364	6.343	— .007	6	34.1
337.5	551	8	10.9	14	43.2	8.760	4.006	11	27.0	2.377	6.388	+ .038	6	32.3
352.5	540	8	11.1	14	44.1	8.736	4.988	11	27.6	2.374	6.363	+ .013	6	33.0
	Means ..	8	6.7	14	39.7	8.595	4.104	11	23.2	2.245	6.350	....	6	33.0

TABLE V.

Containing yearly averages, or those belonging to argument φ_4.

Year.	ϕ_4	λ'_1	λ'_2	H'_1	H'_2	L_2	A_2	H_0	$\lambda'_2-\lambda'_1$
	°	h. m.	h. m.	Feet.	Feet.	h. m.	Feet	Feet.	h. m.
1856	20.5	8 2.4	14 37.4	9.675	5.340	11 19.9	2.167	7.507	6 35.0
1857	1.2	8 0.0	14 31.6	9.821	5.460	11 15.8	2.180	7.640	6 31.6
1858	341.8	8 5.7	14 37.6	9.744	5.438	11 21.6	2.153	7.591	6 31.9
1859	322.5	8 4.4	14 34.0	9.815	5.418	11 19.2	2.199	7.616	6 29.6
1860	303.1	8 6.7	14 33.7	9.764	5.387	11 20.2	2.189	7.575	6 27.0
1861	283.8	8 7.3	14 32.3	9.317	4.860	11 19.8	2.229	7.088	6 25.0
1862	264.5	8 5.0	14 38.7	8.764	4.225	11 21.8	2.270	6.494	6 33.7
1863	245.1	8 9.0	14 39.7	8.773	4.223	11 24.4	2.275	6.498	6 30.7
1864	225.8	8 8.5	14 44.4	8.701	4.240	11 26.5	2.330	6.570	6 35.9
1865	200.4	8 9.8	14 42.0	8.812	4.141	11 25.9	2.335	6.476	6 32.2
1866	187.1	8 7.2	14 43.3	8.797	4.139	11 20.2	2.329	6.468	6 36.1
1867	167.8	8 4.4	14 39.2	8.938	4.292	11 21.8	2.323	6.615	6 34.8
1868	148.4	8 18.0	14 48.8	8.852	4.262	11 33.4	2.295	6.557	6 30.8
1869	129.1	8 14.7	14 45.3	8.702	4.169	11 30.0	2.265	6.435	6 30.6
1870	109.7	8 10.0	14 44.0	7.977	3.413	11 27.0	2.281	5.695	6 34.0
1871	90.4	8 5.3	14 41.0	6.715	2.230	11 23.2	2.242	4.472	6 35.7
1872	71.0	8 3.5	14 40.8	6.696	2.241	11 22.1	2.227	4.468	6 37.3
1873	51.7	8 6.1	14 40.0	6.696	2.337	11 23.0	2.180	4.516	6 33.9
1874	32.4	7 57.8	14 38.1	6.565	2.151	11 18.0	2.207	4.358	6 40.3
Means...		8 6.6	14 39.6	8.596	4.103	11 22.8	2.246	6.349	6 33.0

TABLE VI.

Containing monthly averages, or those belonging to arguments φ_6 and φ_7.

Month.	ϕ_6	ϕ_7	Obs.	λ'_1	λ'_2	H'_1	H'_2	L_2	A_2	H_0	δH_0
	°	°		h. m.	h. m.	Feet.	Feet.	h. m.	Feet.	Feet.	Feet.
January....	15	230	1066	8 10.5	14 39.6	8.344	3.974	11 26.4	2.185	6.159	−0.183
February ..	45	290	999	8 9.0	14 38.6	8.295	3.933	24.4	.181	6.114	.228
March	75	351	1118	8 6.5	14 38.5	8.420	4.019	22.4	.200	6.220	− .122
April......	105	51	1089	8 3.4	14 36.2	8.704	4.272	21.5	.216	6.488	+ .146
May	135	110	1138	8 2.0	14 35.7	8.842	4.385	19.9	.228	6.614	.272
June......	165	168	1086	8 4.0	14 37.7	8.786	4.324	21.9	.231	6.550	.208
July	194	226	1112	8 5.2	14 39.5	8.680	4.200	22.7	.240	6.440	.098
August	223	284	1127	8 6.5	14 41.2	8.685	4.185	24.3	.250	6.435	.093
September	252	344	1094	8 9.5	14 43.4	8.675	4.197	26.6	.239	6.436	.094
October ...	282	44	1128	8 8.9	14 42.6	8.674	4.208	25.8	.233	6.441	+ .099
November..	313	106	1072	8 8.0	14 41.5	8.478	3.994	25.2	.242	6.236	− .106
December ..	344	168	1080	8 10.2	14 41.7	8.178	3.762	24.8	.208	5.975	−0.367
Means....	.....	......	......	8 7.0	14 39.7	8.563	4.121	11 23.8	2.221	6.342	....

6. The observations were first grouped with reference to the arguments φ_1 and φ_2, each group comprising observations belonging to one of 24 equal divisions of each argument. The divisions of φ_1, expressed in times of transit, were from $0^h\ 0^m$ to $0^h\ 30^m$, from $0^h\ 30^m$ to $1^h\ 0^m$, &c., so as to make the averages correspond to the values of $0^h\ 15^m$, $0^h\ 45^m$, &c., or very nearly. The divisions of φ_2 were such as to make the middle of the divisions correspond to 15°, 30°, &c.; and it was assumed that these medium values of the arguments in the case of so many observations would correspond so nearly with the actual average values that they could be adopted instead of the latter without any sensible error. It should be remarked that the values of φ_1, used in the discussion, were those of the moon's transit over the meridian of Washington, instead of the meridian of the port, as is usual; and consequently the values belong to that time, and not to the time of high or low waters, and that a correction must be introduced into the epochs of the results on this account, where the argument is taken for the time of transit over any other meridian, or

for the time of high or low water. The values of φ_2 used were those corresponding to the times of high water.

By summing the averages of the groups in two ways, so as, first, to eliminate the inequalities depending upon φ_2, and, secondly, so as to eliminate the inequality depending upon φ_1, the average values contained in Tables I and II, belonging to the corresponding values of the arguments, were obtained.

7. In the second place, the observations of each year were grouped with reference to the moon's longitude, with a view of determining the inequalities in the semi-diurnal tide depending upon the moon's longitude, and also the amplitude of the diurnal tide, which likewise depends upon the moon's longitude. The observations of each year were grouped separately, in order to determine the inequality in the semi-diurnal tide depending upon φ_4, the longitude of the moon's ascending node. The value of φ_4 belonging to the middle of the year was taken as the value for the groups embracing each year. The value of the moon's longitude, λ, in Tables III and IV, are those belonging to the transit C over the Washington meridian, according to Lubbock's notation; that is, to the fourth transit preceding the time of high water. This arrangement was adopted so that the arguments of longitude which had been used in the discussion of the tidal observations of Boston Harbor, in which the lunitidal intervals were referred to transit C, could be also used in this discussion. All that will be necessary to correct for this will be to introduce a corresponding change in the epochs of the angles in the final results obtained. In order to obtain the amplitude of the diurnal tide, it was necessary to keep the observations of upper and lower transits separate in this case. By first summing and taking the average of the groups belonging to each of the years for each value of λ, the averages in Tables III and IV were obtained; and by summing and taking the average of all the observations belonging to each year, the results of Table V were obtained.

8. The results in Table VI are the averages of all the observations for the whole series belonging to each month; the values of φ_6 and φ_7, being those belonging to the middle of each month. These results are to be used in determining the inequalities depending upon the sun's longitude and true anomaly.

SEMI-DIURNAL TIDE.

9. We shall now determine from the preceding tabular results, the unknown co-efficients and epochs in the theoretical tidal expressions of the amplitude and lunitidal interval of the semi-diurnal tide, and show with what degree of accuracy these expressions, with the unknown constants thus determined, represent the observations. These expressions are (*Tidal Researches* (97) and (99):—

$$(1) \quad \ldots\ldots\ldots\ldots \quad \begin{cases} A_2 = \mathrm{A}_0 \, \Sigma_i \, R_i \cos (\varphi_i - a_i) \\ L_2 = \Sigma_i \, B_i \sin (\varphi_i - \varepsilon_i) \end{cases}$$

in which A_2 is the amplitude of the tide and L_2 the lunitidal interval, the subscript 2 in the general expression common to all the several oscillations being the characteristic of the semi-diurnal tide; also A_0 is the amplitude of the mean tide, and R_i is the ratio between the coefficients of the inequalities of A_2 and the mean amplitude. The expression is put in this form for the purpose of comparing these ratios in the tidal expression with the corresponding ratios in the forces denoted by P_i, the values of which are given in *Tidal Researches*, § 19.

10. *Half-monthly inequality.*—In the averages of Table I, the effect of the diurnal tide is eliminated, and the effect of the ter-diurnal deep-water tide is always extremely small. The mean value, therefore, of $(\lambda'_2 - \lambda')$ in Table I, if the results were not affected by a quarter-diurnal and other tides of shorter period, arising from the shallowness of the water, and therefore called shallow-water tides, would be exactly the fourth part of a mean lunar day, which is $6^h\ 12^m.6$; and the inequality in these values depending upon the values of φ_1 would be very small. It is seen, however, that the mean in the table differs from the fourth of a lunar day about 10 minutes, and that this difference for different values of the argument φ_1 is very different. In deep-water tides also the value of H_0, which is the mean sea-level as determined from the means of the heights of high and low water, would be constant since there is no half-monthly inequality in this mean height in such tides. We see, however, from the column headed δH_0 that this is not the case. The tides of New York Harbor are therefore affected by large shallow-water components, so that the usual

formulæ, based upon the theory of deep-water tides, cannot be used in determining, from the results of Table I, the semi-diurnal tide and its half-monthly inequality without incurring some risk of having the results slightly affected by these shallow-water components. The mean difference of nearly 20 minutes between the intervals from high to low and from low to high waters is caused mostly by the supposition of a quarter-diurnal upon the semi-diurnal tide, which, it is readily conceived, must cause a difference in these intervals, unless the epochs of the semi-diurnal and quarter-diurnal tides are such as to make one of the high waters of the quarter-diurnal tide coincide with a high water of the semi-diurnal tide, in which case the intervals from high to low and from low to high waters would be exactly equal. This is the case in the tides of Boston Harbor, although there are indications of a small quarter-diurnal tide, as shown by a small difference in the mean level of the sea at the times of the syzygies and quadratures as determined from the averages of the heights of high and low water.

It is seen (*Tidal Researches*, 360) that there are six of these shallow-water components, three of which are lunar, solar, or lunisolar quarter-diurnal tides, and one *one-sixth* diurnal, which have periods which are commensurable with the period of the half-monthly inequality; and hence they cause not only the mean difference between the intervals from high to low and from low to high waters, but also a half-monthly inequality in these differences.

11. With the observations of the times and heights merely of the resultant of all the shallow-water terms combined with the diurnal and semi-diurnal tides, it is impossible to so analyze these tides as to determine the amplitudes and epochs of each one, and thus to determine the effects of the shallow-water tides upon the values of A_2 and L_2 in Table I, from which we deduce the amplitude and lunitidal interval of the semi-diurnal tide and their half-monthly inequality. If the heights of high and low water were observed exactly at the interval of one-fourth of a lunar day, the effect of the quarter-diurnal tide upon A_2 in Table I would be eliminated, but it would still affect the value of H_0, but where a high water of the quarter-diurnal tide does not coincide with a high water of the semi-diurnal tide, these intervals, we have seen, are not exactly one-fourth of a lunar day, and hence the difference between H'_1 and H'_2, which is the value of A_2, may be slightly affected from this cause. The best we can do, however, in this discussion is to neglect the consideration of these effects, which we have reason to think are very small. We here see, however, the importance, at least in shallow-water tides, of using the harmonic analysis in the discussion of tidal observations, by means of which all these small components can be determined from the observations.

12. We have (*Tidal Researches*, 333), for the expressions of A_2 in (1),—

$$A_2=\tfrac{1}{4}\,(H_1-H_2+H_3-H_4)=\tfrac{1}{2}\,(H'_1-H'_2)$$

In this expression, however, the values of H_1, H_2, &c., being functions varying with the time, must be taken for the same time; but the values of H'_1, in Table I, are for high water, and of H'_2 for low water; but, instead of reducing them to the same time, we can take the value of A_2, given by the expression above, as belonging to the intermediate time half-way from high to low water, the corresponding lunitidal interval of which is $L_2=\tfrac{1}{2}\,(\lambda'+\lambda'_2)$, given in the table. The values of A_2 and L_2 in the table, then, can be regarded as the averages of the amplitudes of the tide at this intermediate time, and L_2 those of the corresponding lunitidal intervals.

Where the averages are for short intervals of the arguments, these averages can be taken as the true value of the functions belonging to the mean values of the arguments without sensible error; but where the intervals are large, a correction is required. If the values of A_2, in Table I, could be taken as the correct values belonging to the corresponding average values of φ_1, we should have, from the first of (1),—

$$A_2=\mathrm{A}_0\,\{1+R_1\cos(\varphi_1-a_1)+R_{11}\cos(2\varphi_1-a_{11})\}$$

all the other inequalities in the general expression having been eliminated from the averages of Table I. The correct general expression in this case, applicable where A_2 is made to represent the averages for any limits of the arguments whatever, is (*Tidal Researches*, 316):—

$$(2)\quad .\ .\ .\ .\quad A_2=\mathrm{A}_0\,\{1+k\,R_1\cos(\varphi_1-a_1)+k'\,R_{11}\cos(2\,\varphi_1-a_{11})\}$$

in which, expressing $\varphi_{\prime\prime} - \varphi_{\prime}$ in terms of the radius,—

$$(3) \quad . \quad . \quad . \qquad k = \frac{2 \sin \frac{1}{2} (\varphi_{\prime\prime} - \varphi_{\prime})}{\varphi_{\prime\prime} - \varphi_{\prime}} \qquad\qquad k' = \frac{\sin (\varphi_{\prime\prime} - \varphi_{\prime})}{\varphi_{\prime\prime} - \varphi_{\prime}}$$

In these last expressions, $\varphi_{\prime}$ and $\varphi_{\prime\prime}$ are the values of the argument at the two limits of the group of observations, and the space between these limits may be of any extent whatever.

The angle $2\,\varphi_1 = \varphi_{11}$, in the notation of § 5, being a multiple of φ_1, the inequality corresponding to it has not been eliminated from the averages of Table I, and hence this term must be retained. It would likewise be necessary to include, in the expression, terms having the angles $3\,\varphi_1$, $4\,\varphi_1$, &c., if there were any sensible terms having such arguments. But we know from theoretical considerations, as well as from an inspection of the residuals where the results belonging to the expression where only two terms are retained are compared with observation, that all terms beyond the second in the expression are insensible. Of course, sensible co-efficients are brought out in the discussion where such terms are retained; but these are merely of the order of the probable errors of the averages used, and do not indicate real terms. If we had 24 average values of A_2, and should retain so may terms in the expression of (2) that the number of co-efficients and epochs in the expression should amount to the same, we should probably get sensible co-efficients for every term; but, instead of this expression being more correct, it would be less so than where fewer terms are retained, for it would evidently be an expression which would represent all the errors of observation. A too great attempt at refinement, therefore, in this direction, only leads to error.

13. The preceding expression of A_2 may be put into the form—

$$(4) \quad . \quad . \quad . \quad . \quad . \qquad A_2 = \mathrm{A}_0 + M \cos \varphi_1 + N \sin \varphi_1 + M' \cos 2\,\varphi_1 + N' \sin 2\,\varphi_1$$

from which, when M, N, M', and N' are determined, we have, for the co-efficients and epochs,—

$$(5) \quad . \quad . \quad \left\{ \begin{array}{ll} \mathrm{A}_0 R_1 = \frac{1}{k} \sqrt{M^2 + N^2} = \frac{M}{\cos a_1} & \qquad \mathrm{A}_0 R_{11} = \frac{1}{k'} \sqrt{M'^2 + N'^2} = \frac{M'}{\cos a_{11}} \\ \tan a_1 = \frac{N}{M} & \qquad \tan a_{11} = \frac{N'}{M'} \end{array} \right.$$

With the 24 values of A_2, in Table I, and the corresponding values of φ_1, we get, from the preceding expression of A_2, 24 equations of condition for determining A_0, M, N, M', and N'. The solution, by the method of least squares, gives:

$$\mathrm{A}_0 = 2.231 \text{ ft.} \qquad \begin{array}{ll} M = & .4328 \\ M' = & -.0052 \end{array} \qquad \begin{array}{ll} N = & .0838 \\ N' = & -.0087 \end{array}$$

Since the limits of the groups in Table I are at 24 equal intervals of φ_1, we have, in (3) $\varphi_{11} - \varphi_1 = 15°$; and hence we have, in this case,—

$$(6) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad k = .997 \qquad\qquad k' = .989$$

Hence, the averages of the groups might have been used in this case for the true values belonging to the averages of the arguments, since these values differ but little from unity, especially the first, which belongs to the principal term.

With the preceding values, we get, from (5),—

$$\begin{array}{lll} \mathrm{A}_0 R_1 = .4422 \text{ ft.} & \qquad R_1 = .1982 & \qquad a_1 = 10° 57' \\ \mathrm{A}_0 R_{11} = .0102 \text{ ft.} & \qquad R_{11} = .0046 & \qquad a_{11} = 239° \end{array}$$

This latter may be put in the form—

$$\mathrm{A}_0 R_{11} = -.0102 \text{ ft.} \qquad R_{11} = -.0046 \qquad a_{11} = 59°$$

This makes the sign of R_{11} correspond with that of the corresponding value of P_{11} in the forces, and makes the value of the epoch a_{11} in the tidal expressions correspond more nearly with that of the forces, which is 0.

With the preceding values, the expression of A_2, (2), represents the average values of Table I, from observations with a main residual of .016 foot and a maximum one of .065 foot.

14. The general expression of L_2, (1), when applied to the values of L_2 in Table I, can be put, for reasons already given in the preceding case, into the form—

$$(7) \quad \cdots \quad \left\{ \begin{aligned} L_2 &= B_0 + k\, B_1 \sin(\varphi_1 - \varepsilon_1) + k'\, B_{11} \sin(2\,\varphi - \varepsilon_{11}) \\ &= B_0 + M \sin \varphi_1 + N \cos \varphi_1 + M' \sin 2\,\varphi_1 + N' \cos 2\,\varphi_1 \end{aligned} \right.$$

in which—

$$(8) \quad \cdot\ \cdot \quad \left\{ \begin{array}{ll} B_1 = \dfrac{1}{k}\sqrt{M^2 + N^2} = \dfrac{M}{\cos \varepsilon_1} & B_{11} = \dfrac{1}{k'}\sqrt{M'^2 + N'^2} = \dfrac{M'}{\cos \varepsilon_{11}} \\ \tan \varepsilon_1 = -\dfrac{N}{M} & \tan \varepsilon_{11} = -\dfrac{N'}{M'} \end{array} \right.$$

With the 24 values of L_2, in Table I, the second of the preceding forms of expression gives 24 equations for determining, by the method of least squares,—

$$B_0 = 11^h\ 23^m.5 \qquad M = -20^m.5 \qquad N = 10^m.6$$
$$M' = 1^m.7 \qquad N' = -1^m.4$$

By means of (8), we get from these values and the preceding values of k and k' in (6),

$$B_1 = -23^m.1 \qquad \varepsilon_1 = 27^\circ\ 20'$$
$$B_{11} = 2^m.2 \qquad \varepsilon_{11} = 38^\circ\ 7'$$

With these values, the first form of (7) represents the observed average values of L_2, in Table I, with a mean residual of $0^m.8$ and a maximum residual of $2^m.2$.

15. In Table I, the values of φ_1 are those at the time of the moon's transit over the meridian of Washington next preceding the time of high water, while the corresponding values of A_2 and L_2 are those belonging to the time of the middle phase of the tide between high and the following low water, which is $11^h\ 23^m.5 + 12^m.3 = 11^h\ 35^m.8$ later; the $12^m.3$ being the difference between Washington and New York time. Hence, the preceding epochs must be increased by the amounts by which the angles φ_1 and $2\,\varphi_1$ increase in $11^h\ 35^m.8$. The values a_1 and ε_1 must, therefore, be increased by—

$$\frac{11^h\ 35^m.8}{24^h} \,.\, 24^\circ.38 = .483 \times 24^\circ.38 = 11^\circ\ 47'$$

and the values of a_{11} and ε_{11} by twice this amount. We therefore get, for the corrected values,—

$$a_1 = 22^\circ\ 44' \qquad \varepsilon_1 = 39^\circ\ 07'$$
$$a_{11} = 83^\circ \qquad \varepsilon_{11} = 62^\circ.3$$

These corrected epochs are to be used in all theoretical comparisons of the expressions; but, for practical purposes, the time for which the values of the angles are taken is entirely arbitrary, provided the values of the angular epochs always correspond with it. If this time be the time of transit over the meridian of Washington, then the former values of these epochs, a_1, ε_1, &c., must be used in the tidal expressions.

For the value of B_0, which is the mean of L_2, belonging to high water, we must deduct one-eighth of a mean lunar day, which is equal to $3^h\ 6^m.3$; and hence we get for the corrected value of the lunitidal interval of high water, reckoned from the lunar transit over the meridian of New York,—

$$B_0 = 11^h\ 23^m.5 - 3^h\ 6^m.3 = 8^h\ 17^m.2$$

This is for the mean high water of the semi-diurnal tide unaffected by the quarter-diurnal and other tides, which make mean high water occur still 10 minutes earlier.

16. *Lunar parallactic inequality.*—In Table II, all the inequalities except that depending upon the moon's parallax, or mean anomaly, φ_2, are eliminated from the averages. The general form of the expression of A_2, (1), in this case becomes of the form of (2) or (4), except that we must put φ_2 for φ_1 and a_{12} for a_{11} in this case. With the 24 values of A_2, in Table II, given by observation, we get, from (4), with the modification just stated, 24 equations for determining, by the method of least squares,—

$$A_0 = 2.232 \text{ ft.} \qquad M = .3712 \text{ ft.} \qquad N = .1200 \text{ ft.}$$
$$M' = .0365 \text{ ft.} \qquad N' = .0172 \text{ ft.}$$

With these values, and the values of k and k' in (6), we get, from (5)—

$$A_0 R_2 = .3913 \text{ ft.} \qquad R_2 = .1753 \qquad a_2 = 17^\circ 55'$$
$$A_0 R_{12} = .0405 \text{ ft.} \qquad R_{12} = .0185 \qquad a_{12} = 25^\circ.2$$

With these values, the expression of the form of A_2, (2), putting φ_2 for φ_1 in this case, represents the observed values of A_2, with a mean residual of .015 foot, and a maximum residual of .045 foot.

By proceeding in the same manner with the values of L_2 in Table II, using the Equations (7) and (8) in this case with φ_2 and ε_2 instead of φ_1 and ε_1, we get 24 equations, which give:—

$$B_0 = 11^h\, 23^m.5 \qquad M = 3^m.87 \qquad N = -4^m.53$$
$$M' = -0^m.11 \qquad N' = 0^m.06$$

With these values, we get, from (8), modified as above to suit this case,—

$$B_2 = 5^m.99 \qquad \varepsilon_2 = 53^\circ.8$$
$$B_{12} = -0^m.13 \qquad \varepsilon_{12} = 29^\circ.0$$

With these values, the expression of L_2, (7), with the subscripts 1 and 11 changed to 2 and 12, represents the observed values of A_2, in Table II, with a mean residual of $0^m.6$ and a maximum residual of $1^m.5$.

In Table II, the values of the arguments belong to the time of high water; but the values of A_2 and L_2, as deduced from the averages of the table, belong to a time $3^h\, 16^m$ later. Hence the preceding epochs must be increased by the amount by which the angles φ_2 and φ_{12} change in that time; that is, by—

$$\frac{3^h\, 16^m}{24^h} \,.\, 13^\circ.18 = 1^\circ.31'$$

for the epochs a_2 and ε_2, and 3° for a_{12} and ε_{12}. With these corrections, we get, for the corrected epochs,—

$$a_2 = 19^\circ\, 26' \qquad \varepsilon_2 = 55^\circ.3$$
$$a_{12} = 28^\circ.2 \qquad \varepsilon_{12} = 32^\circ$$

17. *Mean lunar declinational inequality.*—In the averages of Table IV, the diurnal tide and all the inequalities of the semi-diurnal tide, including the inequality depending upon the moon's node, are eliminated, except that depending upon the moon's longitude, λ. Besides the term depending upon $\varphi_3 = 2\lambda$ in the general expressions of A_2 and L_2, (1), of the semi-diurnal tide, there is also a small component depending upon the fourth power of the moon's distance from the earth, of which the argument is the moon's longitude, λ, the effect of which is to cause a slight difference in the tides belonging to north and south declinations of the moon. To the terms, therefore, in the general expressions of (1) depending upon the moon's longitude, the principal term of which has the argument $\varphi_3 = 2\lambda$, we must also add a term of which the argument is λ, to represent the term depending upon the fourth power of the moon's distance. Neglecting the term, therefore, in the general expression depending upon $2\varphi_3$ as being insensible in this very small inequality, the expression of the averages of A_2 in the table in this case may be put into the following form:—

$$A_2 = A_0 \left\{ 1 + k R_3 \cos(\varphi_3 - a_3) \right\} + a k' \cos(\lambda - a')$$
$$= A_0 + M \cos\varphi_3 + N \sin\varphi_3 + M' \cos\lambda + N' \sin\lambda$$

By proceeding as in the preceding cases, the 24 values of A_2 give 24 equations, which give—

$$A_0 = 2.245 \text{ ft.} \qquad M = .0845 \text{ ft.} \qquad N = -.0647 \text{ ft.}$$
$$M' = .0213 \text{ ft.} \qquad N' = +.0012 \text{ ft.}$$

In this case, the groups of observations include one-twelfth instead of one twenty-fourth of the argument of the principal term, of which the argument is φ_3, and hence the expressions of (3) give, in this case, $k = .989$ and $k' = .997$. With these, and the preceding values of M, N, &c., the formulæ of (5) give—

$$\text{A}_0 R_3 = .1047 \text{ ft.} \qquad R_3 = .0467 \qquad a_3 = -36° 8'$$
$$a = .0214 \text{ ft.} \qquad a' = 3°.4$$

With these values, the expression of A_2 above represents the average values of A_2 in Table IV, obtained from observation, with a mean residual of .012 foot and a maximum residual of .026 foot. The probable error of the principal co-efficient $\text{A}_0 R_3$ is $\pm$ .0030 foot, or about $\frac{1}{28}$ of an inch. The reason for estimating the probable error in this case only will be explained farther on. But, the residuals being about of the same order, the probable errors do not differ much from that given above in all the other cases.

The expression of the averages of L_2 in Table IV may be put into the form—

$$L_2 = B_0 + k B_3 \sin (\varphi_3 - a_3) + k' b \sin (\lambda - \varepsilon')$$
$$= B_0 + M \sin \varphi_3 + N \cos \varphi_3 + M' \sin \lambda + N' \cos \lambda$$

With the 24 values of L_2 in Table IV, and the corresponding values $\varphi_3 = 2\lambda$, we get, as in preceding cases, 24 equations, which give—

$$B_0 = 11^h 23^m.3 \qquad M = 5^m.60 \qquad N = 0^m.13$$
$$M' = -1^m.33 \qquad N' = -1^m.58$$

These values give, by the formulæ of (8),—

$$B_3 = -5^m.56 \qquad \varepsilon_3 = 88°.7$$
$$b = 2^m.05 \qquad \varepsilon' = 130°$$

The values of the arguments in Table IV, as has been explained in § 7, belong to the transit C of Lubbock's notation, and hence to a time preceding the time to which the values of A_2 and L_2 belong by one and a half mean lunar days plus B_0 plus the difference between Washington and New York time; that is, by—

$$37^h 12^m.7 + 11^h 23^m.2 + 12^m.3 = 48^h 48^m.2$$

The preceding epochs must, therefore, be increased by the amounts by which the angles increase during this time. The amount of change of φ_3 in 24 hours being 26°.36, the epochs a_3 and ε_3 must be increased by 53° 47′, and those of a' and ε' by half this quantity. We therefore get, for the corrected values of the epochs,—

$$a_3 = 17° 39' \qquad \varepsilon_3 = 142°.5$$
$$a' = 30° \qquad \varepsilon' = 156°$$

18. *Lunar nodal inequality.*—In the averages of Table V, all the inequalities have been eliminated except that depending upon the longitude of the moon's node, φ_4. Taking in only one term of the small inequality depending upon φ_4 in this case, the general expression of (1) becomes—

$$A_2 = \text{A}_0 \{1 + k R_4 \cos (\varphi_4 - a_4)\}$$
$$= \text{A}_0 + M \cos \varphi_4 + N \sin \varphi_4$$

With the values of A_2 in Table V, and the corresponding values of φ_4 belonging to the middle of the years, this equation gives 19 equations of condition for determining—

$$\text{A}_0 = 2.246 \text{ ft.} \qquad M = -.0764 \text{ ft.} \qquad N = -.0064 \text{ ft.}$$

Since in this case the period of the argument is divided into equal parts of 18.6 years, the value of $\varphi_{11} - \varphi_1$ in (3) is 19° 20′, and hence we get, from (3), in this case $k = .994$.

With these values, we get, from (5),—

$$\text{A}_0\, R_4 = .0770 \text{ ft.} \qquad R_4 = .0343 \text{ ft.} \qquad a_4 = -4^\circ\, 50'$$

With the preceding values, the preceding expression of A_2 satisfies the values obtained from observation, with a mean residual of .012 foot and a maximum of .027 foot. This is the usual order of residuals, and hence there is no sensible term depending upon $2\,\varphi_4$.

We, in like manner, get for the expression of L_2 in this case,—

$$\begin{aligned}\text{L}_2 &= B_0 + k\, B_4 \sin\,(\varphi_4 - \varepsilon_4) \\ &= B_0 + M \sin\,\varphi_4 + N \cos\,\varphi_4\end{aligned}$$

With the values of L_2 in Table V, and the corresponding values of φ_4, this gives 19 equations of conditions, from which we get—

$$B_0 = 11^{\text{h}}\, 22^{\text{m}}.8 \qquad M = -\,3^{\text{m}}.63 \qquad N = 1^{\text{m}}.60$$

These give, by (8), using the value of k above,—

$$B_4 = -\,4^{\text{m}}.2 \qquad \varepsilon_4 = -\,30^\circ$$

With these values, the expression of L_2 above represents the average values from observation, with a mean residual of $2^{\text{m}}.2$ and a maximum of $7^{\text{m}}.0$. If we compare these residuals with those of all the preceding cases, we find that, while all the others are nearly of the same order, these are about three times larger. By comparing also the values of L_2 in Table V with those of the other tables, it is found that the former are much more irregular. These irregularities must be caused by errors in the time used, which causes the averages of the different years to be several minutes in error in some cases. A part may also be due to personal errors in making the reductions, which were probably made by different persons in different years. All such errors would be eliminated mostly from the averages in all the other tables, and would show themselves only in the yearly averages.

By applying Peirce's criterion to the residuals, it is found that it rejects two of the yearly averages, regarded as one observation; and, from the remaining 17, we then get, instead of the above values,—

$$B_4 = -\,3^{\text{m}}.3 \qquad \varepsilon_4 = -\,17^\circ.6$$

There is no sensible correction of the epochs in this, as in the former cases, on account of the very slow rate of change of the angle φ_4 in this case.

19. *Solar declinational and parallactic inequalities.*—The averages of Table VI contain two inequalities; the one depending upon the sun's anomaly, and the other upon its longitude, or declination. The period of the former is sensibly double that of the latter. These inequalities are very small, and the general expression of A_2, (1), in this case, becomes—

$$\begin{aligned}A_2 &= \text{A}_0\,\{1 + k\,R_6 \cos\,(\varphi_6 - a_6) + k'\,R_7 \cos\,(\varphi_7 - a_7)\} \\ &= \text{A}_0 + M \cos\,\varphi_6 + N \sin\,\varphi_6 + M' \cos\,\varphi_7 + N' \sin\,\varphi_7\end{aligned}$$

With the 12 values of A_2 in Table VI, and the corresponding values of φ_6 and φ_7 belonging to the middle of the months, we get from this 12 equations for obtaining—

$$\text{A}_0 = 2.221 \text{ ft.} \qquad M = -\,.021 \text{ ft.} \qquad N = -\,.020 \text{ ft.} \qquad M' = .004 \text{ ft.} \qquad N' = .008 \text{ ft.}$$

In this case, each of the 12 monthly groups of observations include 30° of the angle φ_6 and 60° nearly of φ_7; and hence, by the first of (3), we get $k = .988$ and $k' = .953$. The corrections, however, depending upon these quantities, although larger than usual proportionally, are of no consequence on account of the smallness of the inequalities to which they are applied.

With these values, we get, from (5),—

$$A_0 R_6 = .029 \text{ ft.} \qquad R_6 = .013 \qquad a_6 = 224^\circ$$
$$A_0 R_7 = .009 \text{ ft.} \qquad R_7 = .004 \qquad a_7 = 117^\circ$$

With these values, the preceding expression of A_2 represents the observed values, with a mean residual of .006 foot and a maximum of .012 foot. The co-efficient of the last inequality in the preceding expression is so nearly of the order of the residuals that it can scarcely be regarded as a real inequality.

In like manner, we get, in this case, for the expression of L_2,—

$$\begin{aligned} L_2 &= B_0 + k\,B_6 \sin(\varphi_6 - \varepsilon_6) + k'\,B_7 \sin(\varphi_7 - \varepsilon_7) \\ &= B_0 + M \sin\varphi_6 + N \cos\varphi_6 + M' \sin\varphi_7 + N' \cos\varphi_7 \end{aligned}$$

With the values of L_2 in Table VI, and the corresponding values of the angles, we, in like manner, obtain 12 equations for determining the values of—

$$B_0 = 11^h\,23^m.8 \qquad M = -\,1^m.22 \qquad N = 1^m.72 \qquad M' = -\,0^m.95 \qquad N' = 0^m.33$$

With these values we get (8),—

$$B_6 = 2^m.2 \qquad \varepsilon_6 = 126^\circ$$
$$B_7 = 1^m.0 \qquad \varepsilon_7 = -\,19^\circ$$

20. *Mean sea-level.*—The average of high and low waters, denoted by H_0, in the tables of averages, are not the heights of the true mean sea-level, as has been stated, when the tides are affected by shallow-water terms. Theory does not give any half-monthly inequality in the height of mean sea-level in deep-water tides; and all the other inequalities, depending upon parallax and declination, are so extremely small that it is impossible to deduce them from the preceding tables of averages which are affected by large shallow-water terms. There is a theoretical shallow-water component, with a half-monthly period, which would affect the mean level, and this may, in some cases, be sensible; but the column in Table I headed δH_0 does not represent this inequality, but is the effect mostly of the quarter-diurnal components which are not eliminated in the averages of high and low water.

The column headed H_0 in Table V shows that there was a change of more than three feet in the zero-plane of the tide-gauge between the beginning and the end of the series. An abrupt change of about 1.1 feet seems to have been made about the middle of the year 1861, and another of nearly two feet some time during the year 1871. On account of these changes, we cannot determine whether there has been any secular change of sea-level during the time of the series of observations.

DIURNAL TIDE.

21. The diurnal tide can be determined from the averages of Table IV, which are given separately for each of the high and low waters of a lunar day. If there were no ter-diurnal tide, or quarter-diurnal and other shallow-water components, we should have, for the mean values at the bottom of that table, $\lambda_1 = \lambda_3$, $\lambda_2 = \lambda_4$, $H_1 = H_3$, and $H_2 = H_4$. In obtaining the values, therefore, of $\frac{1}{2}(\lambda_1 - \lambda_3)$, $\frac{1}{2}(\lambda_2 - \lambda_4)$, $\frac{1}{2}(H_1 - H_3)$, and $\frac{1}{2}(H_2 - H_4)$, due to the effects of the diurnal tide alone, we can correct in a great measure for the effects of all the other components of short period by subtracting from each of these differences the differences of the means at the bottom. For instance, we must diminish each of the 24 values of $(\lambda_1 - \lambda_3)$ by $-\,4^m.0$; and so of the others. Since, moreover, the averages belonging to low waters belong to a time equal to six lunar hours later than those of high waters, and it is necessary, in determining the amplitude of the diurnal tide, to have these quantities for the same absolute time, we have applied a small correction by means of proportional parts of the differences to those of the low waters, in order to reduce them to the times of high waters. With the preceding corrections or reductions applied to the differences of Table IV, we obtain those of Table VII.

TABLE VII.

Containing averages from which the diurnal tide is deduced, and also the corresponding theoretical values.

λ	Observation.						Theory.			
	$\frac{1}{2}(\lambda_1-\lambda_3)$	$\frac{1}{2}(\lambda_2-\lambda_4)$	$\frac{1}{2}(H_1-H_3)$	$\frac{1}{2}(H_2-H_4)$	M_1	Δ	$\frac{1}{2}(\lambda_1-\lambda_3)$	$\frac{1}{2}(\lambda_2-\lambda_4)$	M_1	Δ
°	*m.*	*m.*	*feet.*	*feet.*	*feet.*	°	*m.*	*m.*	*feet.*	°
7.5	+ 5.6	+ 8.2	+ 0.334	+ 0.046	0.386	7.9	+ 1.2	+ 8.6	0.306	12.4
22.5	4.3	10.1	.381	+ .018	.382	2.7	+ 0.5	9.8	.367	3.5
37.5	+ 1.4	10.6	.403	− .008	.403	358.8	− 0.2	10.3	.410	357.1
52.5	0.0	12.1	.428	.073	.433	350.3	1.9	11.0	.429	351.6
67.5	− 2.0	12.5	.385	.129	.405	341.4	3.3	9.9	.421	346.4
82.5	4.0	12.0	.367	.100	.381	344.7	2.6	9.4	.389	340.5
97.5	4.5	10.4	.330	.150	.363	335.4	4.0	8.5	.335	332.9
112.5	4.7	8.2	.225	.163	.276	324.0	4.2	5.8	.267	321.9
127.5	6.2	4.0	+ .101	.162	.191	302.1	4.2	+ 2.6	.196	301.7
142.5	5.0	+ 1.2	− .005	.159	.159	272.0	4.1	− 0.1	.151	269.6
157.5	5.5	− 0.6	.120	.134	.180	228.0	3.4	3.0	.170	230.8
172.5	5.8	4.1	.184	.086	.203	205.0	2.2	4.7	.235	206.8
187.5	4.7	7.5	.294	.062	.300	191.9	1.6	7.6	.306	192.4
202.5	2.7	10.5	.354	− .014	.355	182.3	− 0.4	9.1	.367	183.5
217.5	− 0.5	12.3	.407	+ .023	.409	176.7	+ 0.6	10.8	.410	177.1
232.5	+ 2.7	12.7	.452	.108	.469	166.5	2.8	11.7	.429	171.6
247.5	2.3	13.9	.397	.112	.413	164.2	2.9	10.2	.421	166.4
262.5	2.7	12.1	.380	.124	.400	161.9	3.2	9.8	.389	160.5
277.5	2.9	10.4	.296	.149	.331	153.2	3.8	7.6	.335	152.9
292.5	4.2	7.5	.208	.182	.276	138.7	4.7	5.3	.267	141.9
307.5	5.1	4.4	.118	.158	.197	126.7	4.0	3.0	.196	121.7
322.5	6.0	− 1.0	− .007	.150	.150	92.9	3.8	− 0.2	.151	89.6
337.5	4.7	+ 2.6	+ .055	.100	.114	61.0	2.6	+ 1.4	.170	50.8
352.5	+ 5.6	+ 5.4	+ 0.197	+ 0.070	0.209	19.6	+ 1.8	+ 5.1	0.235	26.8

By putting the sines of small arcs, or those differing but little from 180°, equal to the arcs themselves, or their differences from 180°, and likewise the cosines of arcs differing but little from 90° or 270°, equal to the differences, and also neglecting the terms depending upon A_3, the amplitude of the ter-diurnal tide, since the effect of this has been corrected for, together with those of the shallow-water components in the tabular results above, we get, from *Tidal Researches*, (161), (162), and (325),—

$$\tfrac{1}{2}(\lambda_1-\lambda_3)=\frac{M_1 \sin \Delta}{4A_2} \qquad \tfrac{1}{2}(\lambda_2-\lambda_4)=\frac{M_1 \cos \Delta}{4A_2}$$

$$\tfrac{1}{2}(H_1-H_3)=M_1 \cos \Delta \qquad \tfrac{1}{2}(H_2-H_4)=M_1 \sin \Delta$$

in which M_1 is the amplitude of the lunar diurnal tide; Δ is the time, expressed in arc, by which the high water of the diurnal tide follows that of the semi-diurnal tide next following the moon's upper transit; and A_2 (=2.31 feet) is the mean amplitude of the semi-diurnal tide. The small inequality of A_2 depending upon longitude can be neglected in these expressions, since the quantities are all small. The expressions of $\frac{1}{2}(\lambda_1-\lambda_3)$ and $\frac{1}{2}(\lambda_2-\lambda_4)$ are in terms of the radius, and must be reduced to time.

With the values of $\frac{1}{2}(H_1-H_5)$ and $\frac{1}{2}(H_2-H_4)$ in the preceding table, the last two of the preceding equations give the corresponding values of M_1 and Δ in the table. With these values of M_1 and Δ, the first two of these equations give the computed values of $\frac{1}{2}(\lambda_1-\lambda_3)$ and $\frac{1}{2}(\lambda_2-\lambda_4)$ in Table VII. These could not be expected to agree exactly with the observed values, since the latter, and likewise the data from which the former were computed, are all affected by the various irregularities not completely eliminated by the number of observations. But, besides these irregular differ-

ences, a very small systematic difference is observable between the observed and computed values, which was to be expected, since the corrections for the shallow-water components were necessarily only partial and incomplete.

22. The values of M_1 in the preceding table give an extraordinary result, which has never been brought out before in the discussion of the observations of any tidal station. The lunar diurnal tide has always been supposed to vanish at or near the time of the moon's crossing the equator; but the result obtained here shows that, in New York Harbor, the diurnal tide never vanishes, but that there is a minimum diurnal tide, with an amplitude of about two inches, near the time of the moon's crossing the equator, while the amplitude of the maximum tide near the time of greatest declination is less than six inches. The theoretical explanation of this will be given farther on.

If, in Table VII, we put—

$$M_1 = A_0 + A_1 \sin (2\lambda - a_1) + A_2 \sin (4\lambda - a_2)$$

and determine, by methods heretofore adopted, the most probable values of the constants, we get—

$$A_0 = .306 \text{ ft.} \qquad A_1 = .141 \text{ ft.} \qquad A_2 = .018 \text{ ft.} \qquad a_1 = 21^\circ.6 \qquad a_2 = 29^\circ$$

With these values, the preceding expression represents the observed values of M_1 in Table VI, with a mean residual of .011 foot and a maximum one of .030 foot. This is the usual order of the residuals, depending upon the uneliminated irregularities of the observations; and both the smallness of the residuals and the small value of A_2 show that the above expression represents very accurately the true values of M_1.

Since the values of λ in Table VII belong to the transit C over the Washington meridian, which is $45^h\ 42^m$ before the time of high water next following the moon's upper transit, to which time the values of M_1 belong, the preceding epochs must be increased by the amount by which the angles change in that time, which, for 2λ, is $50^\circ.2$, and, for 4λ, twice that amount. With the preceding values of the constants, and these corrections in the epochs, the preceding expression of M_1 becomes, in feet,—

$$M_1 = .306 + .141 \sin (2\lambda - 71^\circ.8) + .018 \sin (4\lambda - 129^\circ)$$

This expression gives $M_1 = .429$ foot for the maximum value, and $M_1 = .147$ foot for the minimum value.

From the epochs in this expression of M_1, it is seen that the maximum of the diurnal tide occurs before the time of greatest declination, which is another unusual result in connection with this tide; for generally the maximum of the tide follows the time of the maximum of the force upon which it depends.

The first and principal periodic term in the expression above is a maximum when $\lambda = 80^\circ.9$; and hence, as λ changes $13^\circ.18$ in a day, we have—

$$\frac{90^\circ - 80^\circ.9}{13^\circ.18} = 0.690$$

for the time in the decimal of a day by which the maximum occurs before the greatest declination, that is, before the maximum of the force; and the effect of the other small term does not change sensibly the time of maximum of the whole expression, since the epoch is such as to make it either a maximum or a minimum almost at the same time that the other is a maximum.

From an inspection of the values of Δ in Table VII, it is seen that the high water of the diurnal tide at the time of maximum and near the time of greatest declination, occurs very nearly at the time of high water of the semi-diurnal tide, but that near the time of the moon's crossing the equator, when this tide is a minimum, it occurs near the time of the low water of this tide; and hence it has a range of about six hours with regard to the time of the moon's transit.

COMPARISONS OF THEORY WITH OBSERVATION.

23. The potential of the disturbing forces giving rise to semi-diurnal tides may be put into the form of (*Tidal Researches*, (35))—

$$V_2 = N_2 \cos (2 \varphi + 2 \varpi)$$

in which both the co-efficient, N_2, and the angle, φ, have inequalities depending upon the time. The expression of the co-efficient is of the form (*Tidal Researches*, (34))—

$$N_2 = B_2 \, C_2 \, \Sigma_i \, P_i \cos \varphi_i$$

in which B_2 is a function of the latitude of the place, and C_2 a known constant if the mass of the moon is known, and P_i expresses the ratios between the co-efficients of the several inequalities and the constant and mean co-efficient to which $P_0 = 1$ belongs. Corresponding to these, we have the tidal expression (*Tidal Researches*, (96))—

$$Y_2 = A_2 \cos (2 \varphi_1 - L_0)$$

in which the amplitude, A_2, is expressed in the form—

$$A_2 = A_0 \, \Sigma_i \, R_i \cos (\varphi_i - a_i)$$

as already given in (1). The expressions of N_2 and A_2, it is seen, are similar in form, and R_i expresses the ratios between the co-efficients in the inequalities of A_2 and the mean constant amplitude, A_0, as P_i expresses the corresponding ratios in the forces. The values of a_i indicate the differences in the epochs of the angles of the inequalities in the forces and those of the corresponding tidal expressions.

The values of R_i and a_i belonging to the principal inequalities in the preceding expression have been obtained for New York Harbor, and it will now be interesting to compare them with the corresponding values in the forces; the values of P_i being given below, and the epochs to which a_i corresponds being 0. As the tidal observations of Boston Harbor and of Brest have also been discussed upon the same principle, and the values of R_i and a_i have likewise been determined for the principal inequalities, it will be interesting to have all in the same connection, for the sake of comparisons with each other and with the corresponding quantities in the forces. We therefore give the following values of P_i, belonging to a mass of the moon equal to .0125, with the corresponding values of R_i and a_i, for New York, Boston, and Brest; those of New York being collected from the preceding pages, those of Boston being taken from the Coast Survey Report for 1868, and those of Brest from *Tidal Researches*, p. 184. The epochs of the two latter have been reduced to the times of high water, for which those of New York are given, by means of reductions similar to those in the preceding pages.

Values of P_i, and of R_i and a_i for New York, Boston, and Brest.

			New York.	Boston.	Brest.		New York.	Boston.	Brest.
$P_1 =$	.4433	$R_1 =$	.1982	.1388	.3590	$a_1 =$	22°.1	39°.0	34°.7
$P_2 =$	.1496	$R_2 =$	.1753	.1624	.1592	$a_2 =$	19°.4	29°.2	20°.2
$P_3 =$	.0982	$R_3 =$	.0467	.0225	.0793	$a_3 =$	17°.6	47°.0	38°.2
$P_4 =$	− .0370	$R_4 =$	− .0343	− .0235		$a_4 =$	− 4°.8	− 11°.0	
$P_6 =$	.0096	$R_6 =$	.0130	.0077	.0017	$a_6 =$	224°	245°	9°
$P_7 =$	.0055	$R_7 =$	.0040	− .0019	.0015	$a_7 =$	117°	58°	47°
$P_{11} =$	− .0480	$R_{11} =$	− .0046	− .0045	− .0357	$a_{11} =$	82°	97°	67°
$P_{12} =$	.0062	$R_{12} =$	− .0185	.0107	.0085	$a_{12} =$	25°	44°	32°

By comparing the values of R_1, R_3, R_4, and R_{11} with those of the corresponding values of P_i, it is seen that they are smaller for each of the three ports, and that those of New York and Boston are very much smaller, while those of Brest differ very much less. But the values of R_2 for each of the three ports are a little greater than that of P_2 belonging to the forces.

The values of the epochs, a_i, of the principal inequalities being positive, indicate that the maxima of the inequalities occur after the corresponding maxima in the inequalities of the forces. By dividing the values of a_i by the daily change of the corresponding angles, we get the amount of this delay in the times of the maxima of the inequalities in the tides, from which it is seen that this is very different in the different inequalities of the tides of the *same* place, as well as very different in the *same* inequality for tides of *different* places. This amount of retardation, in the case of the first and principal inequality, has been called the *retard*, and, by Dr. Whewell, *the age of the tide*, upon the hypothesis that our tides are derived from those of the Southern Ocean, and that this delay in the time of the maximum is simply the time required for it to arrive as a free tidal wave to the ports of the North Atlantic. The great difference, however, in the retard of Boston and New York, now shown by the preceding results, entirely disproves this hypothesis.

24. The theoretical relation between R_i and P_i for deep-water tides, neglecting terms of the third order, is (*Tidal Researches*, (97))—

$$R_i = \frac{P_i + m_i E Q_i}{1 + F}$$

in which E and F are unknown constants, to be determined from observation for each port. With the values of P_i, m_i, and Q_i, belonging to the first four inequalities, and introducing a correction of P_i, which has been omitted above, for the correction of the moon's mass, μ, we get, for New York Harbor, with the values of R_i, from observation,—

$$.1982\,(1 - F) = .4433 - 28.0\,\delta\mu + (.1827 - 15.5\,\delta\mu)\,E$$

$$.1753\,(1 - F) = .1496 + 3.8\,\delta\mu - .0501\,E$$

$$.0467\,(1 - F) = .0982 + 1.0\,\delta\mu + (.0479 - 0.5\,\delta\mu)\,E$$

$$.0343\,(1 - F) = .0370$$

The first three of these equations are sufficient for the determination of the unknown constants and the correction of the moon's mass, and their solution gives—

$$\mu = \frac{1}{66}$$

$$E = -.963$$

$$F = -.245$$

This value of μ we know is much too large, and its error is not due to errors of observation, but arises from the preceding conditions, which hold only for deep-water tides, not being applicable to the New York tides, which we have seen are affected by large shallow-water components. The large value of F, also, which is obtained in some places, is due to the effect of the shallow-water components; for it has been shown in *Tidal Researches* that the effect of these components is to smooth down in some measure all the inequalities, which effect is represented by F in the preceding expression when it has a negative value. In deep-water tides the value of F is, perhaps, insensible, and it is very small at Brest.

The declination-inequality at New York Harbor, upon which the third of the preceding conditions is based, is very small, being little more than an inch; and the probable error (§ 17), as deduced from the observations, amounts to one thirty-fifth part, and this would affect the determination of the moon's mass in about the same ratio; so that the probable error in the preceding determination from this source is probably not very large; and in ports where the declination-inequality is six times as large, as it is at Brest, the error in the determination of the moon's mass, arising from errors of observation, would be proportionally decreased, and hence would be quite small. Almost

the whole weight of the determination is thrown upon this inequality, and it is little affected by small errors in the values of R_1 and R_2 obtained from observation. We have reason, therefore, to think that the moon's mass would be accurately given by the preceding conditions, in the case of deep-water tides, having a large amplitude and consequently a large declination inequality; for the absolute amount of the probable error of this inequality as obtained from observation does not depend much upon the amplitude of the tide.

The shallow-water components affecting the preceding conditions are so numerous, and their relations to each other and to the components depending directly upon the forces, with regard to amplitude and epoch, may be so different in different ports, that we do not know what their general tendency is; but it seems to be to make the moon's mass too great generally, though they may no doubt have the contrary effect sometimes.

The preceding value of E is large, as in the case of the Boston tides, and has the same sign. The effect of this is to diminish the first and third inequalities, indicated by the values of R_1 and R_3, and to increase the lunar parallactic inequality, of which the ratio to the mean tide is R_2. The value of F is negative, as in the tides of Boston Harbor, but much less. The effect of this is to diminish all the inequalities in the same ratio; but it does not diminish the parallactic inequality as much as it is increased by the term depending upon E, and the difference leaves the value of R_2 a little greater than P_2. In the case of the first and third inequalities, the effects of the terms depending upon E and F are both in the same direction, and hence R_1 and R_3 are very much less than P_1 and P_3. The value of F, as has been stated, depends mostly, if not entirely, upon the effect of the shallow-water terms, and represents in the preceding expression of R_i only approximately the effect of those terms; and hence the preceding conditions, from the theory of deep-water tides, in the case of the New York tides, affected by shallow-water components, are best satisfied with a mass of the moon which is too large.

The value of F, obtained from the first three of the preceding equations, substituted in the last one, gives $R_4 = -.0300$ instead of $-.0343$, as obtained from observation. The difference corresponding to $.0043\ A_0$ in the absolute co-efficient of the inequality, being about only one-eighth of an inch, may be regarded as falling within the limits of the possible errors of observation.

25. The values of the epochs, α_i, being positive in the first three principal inequalities indicates that the maximum of the tide follows some time after the maximum of the forces. The daily rate of increase of the angles φ_i being respectively 24°.38, 13°.18, 026°.36, by dividing the preceding values of α_1, α_2, and α_3 by these quantities, we get, respectively, 1.922, 1.45, and 0.61 days for the times that the maximum of the several inequalities in the tides follows that of the forces. These times differ very much among themselves, and are all much smaller than in the case of the tides of Boston Harbor, in which, on the average, they amount to about two days. By the equilibrium-theory, these times should vanish, and by the theory of deep-water tides, neglecting quantities of a third order, which must be generally very small, these times should be the same for all the inequalities. These epochs, then, as well as the co-efficients of the inequalities, are no doubt much affected by the shallow-water components, and the large differences observed are not due alone to these neglected quantities of a third order in the theory of deep-water tides.

The value of α_4 should be sensibly 0, on account of the very long period of the fourth inequality; and the small value, $-4°.8$, obtained from observation, falls within the limits of the possible errors of observation, for the epoch cannot be very accurately determined on account of the smallness of the inequality.

26. In the case of the sixth and seventh inequalities, the values of R_6 and R_7 differ but little from those of P_6 and P_7, all being very small; but when we consider the epochs which in these inequalities of long period should by theory be sensibly 0, we see that there is no correspondence between theory and observation; and this has been found to be the case generally at all tidal stations. The results obtained from observation have been supposed to be due in a great measure to meteorological causes connected with the different seasons; for, since the very small theoretical inequalities have a yearly and half-yearly inequality, the effects from meteorological causes would not be eliminated from the results in the discussion of the observations; but still it is not very clear how the mere range of oscillation of the tides should be affected sensibly by the different seasons.

By referring to the column headed δH_0 in Table VI, it is seen that the height of the mean level of the sea is greater during the summer than the winter. This same annual inequality in the height of the sea-level has been obtained in the case of the tides at Boston and at Brest, except that the maxima at the latter places seem to come later in the fall. A similar result has been also obtained in the case of the tides at Key West, Fla. The observed annual inequality in the atmospheric pressure accounts for only a very small part of this inequality of the height of sea-level; but the balance is probably caused by annual changes in the winds and in the ocean-currents, which have an effect upon the mean sea-level.

27. From *Tidal Researches*, (99), we have, for the expression of the lunitidal interval,—

$$L_2 = \Sigma_i \, Bi \sin (\varphi i - \varepsilon_i)$$

We give below the values of B_i and ε_i for the principal inequalities, as determined from observation for New York Harbor, and collected from the preceding pages; and likewise the corresponding values for Boston Harbor and Brest, for the sake of comparison:—

	New York.	Boston.	Brest.		New York.	Boston.	Brest.
B_1	$=-23^m.1$	$-22^m.6$	$-43^m.0$	ε_1	$=+38^\circ.9$	$+49^\circ.5$	$+45^\circ.7$
B_2	$=+6^m.0$	$+6^m.2$	$+5^m.8$	ε_2	$=+55^\circ.3$	$+72^\circ$	$+83^\circ$
B_3	$=-5^m.6$	$+5^m.3$	$+3^m.8$	ε_3	$=+142^\circ$	$+60^\circ$	-58°
B_4	$=-3^m.3$	$-2^m.5$		ε_4	$=-18^\circ$	-50°	
B_6	$=-2^m.2$	$-3^m.9$	$+0^m.5$	ε_6	$=-54^\circ$	-73°	-53°
B_7	$=+1^m.0$	$-0^m.6$	$-2^m.0$	ε_7	$=-19^\circ$	-10°	-60°
B_{11}	$=+2^m.2$	$+2^m.0$	$+8^m.1$	ε_{11}	$=+52^\circ$	$+112^\circ$	$+85^\circ$
B_{12}	$=-0^m.1$	$+1^m.0$	$+1^m.0$	ε_{12}	$=+54^\circ$	$=50^\circ$	-62°

The value of B_1, which is the co-efficient of the half-monthly inequality, is very nearly the same at New York as at Boston, but is very much less than the value at Brest, which is very nearly the value for European ports generally. By comparing the value of a_1, given on a preceding page, with that of ε_1 above, it is seen that the former is little more than half as great as the latter; and hence what has been called the age of the tides from the heights is much less than the age from the times, the former being, as has been found, 0.922 day, and the latter may be readily found to be 1.48 days. A like difference is seen in the case of the tides at Boston and Brest, but it is much less.

We have the following theoretical relations, expressed in minutes, for the first three inequalities of L_2 (*Tidal Researches*, (132,) (133)), which should be satisfied by observation:—

	Residuals.
$B_1 \cos (\varepsilon_1 - a_1) = -53.7 + 4320\,\delta\mu - (22.4 - 1190\,\delta\mu)\,E + 1.2 \sin^2 a_1 - 4.2\,R_1$	$+2.3$
$B_2 \cos (\varepsilon_2 - a_2) = -(4.1 + 187\,\delta\mu)\,E + 13.0 \sin^2 a_2 - 2.2\,R_2$	$+0.1$
$B_3 \cos (\varepsilon_3 - a_3) = -2.2 + 120\,\delta\mu - (5.2 + 48\,\delta\mu)\,E - 5.1 \sin^2 a_3 - 4.5\,R_3$	-2.6

With the preceding values of B_i, ε_i, and a_i, obtained from observation, and also the preceding values of E and $\delta\mu$, obtained from the theoretical relations of the inequalities of the amplitudes of the tides, these equations are satisfied with the residuals annexed. But these relations, based upon the theory of deep-water tides, as those in § 24, require too large a mass of the moon to satisfy them.

From the values of B_4 and ε_4 above, it is seen there is a small inequality in the lunitidal interval, depending upon the moon's node, both at New York and Boston, and that the co-efficients and epochs of the inequality do not differ very greatly at the two places. There is no corresponding inequality in the theoretical expression, unless it depends upon friction, which is as a greater power than the first power of the velocity; and, even upon this hypothesis, the *epochs* of the observed inequality, especially in the case of the New York tides, are not what theory would require. This inequality, therefore, which seems to be clearly brought out from the observations both of New York and Boston, does not seem to be satisfactorily explained by theory.

From the values of B_6 and ϵ_6, it is seen that there is a considerable annual inequality at both New York and Boston in the lunitidal interval; while, in the theoretical expression, the annual inequality is scarcely sensible, and the epochs do not at all correspond with those of observation. This inequality, therefore, as the corresponding one in the amplitude of the tides, must depend in some way upon meteorological causes. The theoretical semi-annual inequality is also very small; but for this, observation gives likewise a very small inequality.

The values of B_{11} at New York and Boston are small, while at Brest its value is four times as large. This is merely an inequality of the second order, included under the same argument with that of the half-monthly inequality, and the values of B_1 and B_{11} show that the expression is much more convergent at New York and Boston than at Brest.

28. In the averages of Table III, the effect of the solar diurnal tide is eliminated, and the diurnal tide obtained belongs entirely to the moon. Neglecting the parallactic and nodal inequalities, which are also eliminated from the averages, the potential of the lunar force producing the diurnal tide may be resolved into two harmonic components of the form $K \cos i\, t$ and $K \cos i'\, t$, to which correspond the tidal components (*Tidal Researches*, (164))—

$$A \cos (i\, t - \epsilon) \text{ and } A' \cos (i'\, t - \epsilon')$$

in which—

$$A = \mathrm{A}_0 (1 + u\, E) \qquad i = i_0 + u \qquad \epsilon = \mathrm{L}_0 + u\, G$$
$$A' = \mathrm{A}_0 (1 - u\, E) \qquad i' = i_0 - u \qquad \epsilon' = \mathrm{L}_0 - u\, G$$

In these expressions, the origin of t must be taken so as to make $u\, t = -\frac{1}{2}\pi$ when the moon's longitude, λ, equals 0, or $u\, t = 0$ when the moon has its greatest northern declination, and $u = .230$ in terms of the radius, has such a value that the period of $u\, t$ is equal to the period of the moon's tropical revolution. The values of A_0, L_0, E, and G can only be determined from observation.

29. By combining the preceding tidal components by means of the general formula (*Tidal Researches*, (22)), we get, by putting M_1 for the resulting amplitude of the diurnal tide,—

$$A \cos (i\, t - \epsilon) + A' \cos (i'\, t - \epsilon') = M_1 \cos (i\, t - \epsilon + E)$$

in which, since $(i\, t - \epsilon) - (i'\, t - \epsilon') = 2\, u\, t - 2\, n\, G$—

$$M_1 = \mathrm{A}_0 \sqrt{2} \sqrt{1 + u^2 \epsilon^2 + (1 - u^2 \epsilon^2) \cos 2\, (u\, t - u\, G)}$$

$$\tan E = -\frac{A' \sin 2\, (u\, t - u\, G)}{A + A_1 \cos 2\, (u\, t - u\, G)} = -\frac{(1 - u\, \epsilon) \sin 2\, (u\, t - u\, G)}{1 - u\, \epsilon + (1 - u\, \epsilon) \cos 2\, u\, t - u\, G)}.$$

The value of M_1 is a maximum when $u\, t = u\, G$ or $t = G$, and a minimum when $u\, t - u\, G = 90°$ The maximum of the tide, therefore, occurs at a time $t = \mathrm{G}$ after the maximum of the forces. It has been found (§ 22) that the value of G is negative in the New York tides, and equal to 0.69 of a day. From the preceding expression of M_1 we get, for the maximum, $M_1 = 2\, A_0$, and for the minimum, when $2\, (u\, t - u\, G)$ equals $\pm\, 180°$, $M_1 = \pm\, 2\, u\, E\, \mathrm{A}_0$. This occurs G days after the moon has passed the equator, which, in this case, is *before* it has passed, since G is negative. The diurnal tide, therefore, never vanishes when circumstances are such as to give a value to E, which makes the term $2\, u\, E\, \mathrm{A}_0$ sensible. The general expression, therefore, A_1, in *Tidal Researches*, (97), when applied to the diurnal tide, is not strictly correct, since it neglects this quantity of a second order, and assumes that the tide vanishes when the moon is near the equator, as has always been supposed. This term, however, must generally be very small, if not entirely insensible, and it was so found to be in the case of the tides of Boston Harbor. Peculiar local circumstances, however, may be such as to give E a very large value at some stations, and this must be the case in New York Harbor.

30. It was found from observation (§ 22) that the maximum value of the amplitude of the lunar diurnal tide is $M_1 = .463$ foot, and the minimum value is $M_1 = .185$ foot. Hence we have $2\,A_0 = .429$ foot and $\pm\, 2\, u\, E\, A_0 = .147$ foot. These, with the value of $u = .230$, already given, give $A_0 = .214$ foot and $E = \pm\, 1.50$, which is very much greater than the value of ε in the semi-diurnal tide of New York Harbor; and this latter value is very much greater than the value belonging to European ports generally.

The preceding conditions do not determine the sign of E, and consequently they do not determine whether A or A' is the greater amplitude. This can only be determined by comparing the epochs denoted by Δ in Table VII with those of the preceding expression, $M_1 \cos\,(i\,t - \varepsilon + E)$, the resultant of the two harmonic components of the lunar diurnal tide, to which the results of Table VII belong; the solar diurnal tide and the inequalities of parallax, &c., having been eliminated from the averages by the grouping of the observations. With the preceding values of i and ε, we have—

$$M_1 \cos\,(i\,t - \varepsilon + E) = M_1 \cos\,(i_0\,t + u\,t - L_0 - u\,G + E)$$

The expression of the mean semi-diurnal tide being $A_0 \cos 2\,(i_0\,t - L_0)$, we shall have, for the time by which the diurnal tide follows the semi-diurnal, expressed in arc,—

$$\Delta = \mathrm{L}_0 + u\,G - E - \lambda + \tfrac{1}{2}\,\pi - L_0$$

putting for $u\,t$ its equivalent $\lambda - \frac{1}{2}\,\pi$. In these expressions, the true longitudes may be used instead of the mean without sensible error where the observations belong to true longitudes. The value of Δ given by this expression should agree with that in Table VII, given by observation. The value of L_0 in time, which is the mean lunitidal interval of the semi-diurnal tide, has been found to be $8^h\ 7^m.2$.

It is found by trial that the results given by this expression of Δ above cannot correspond with those of Table VII unless $A > A'$ in the preceding expression of tan E, which enters into Δ; and hence that the preceding value obtained for E must be positive. By putting L for the constant part of the expression of Δ, we have—

$$\Delta = L - E - \lambda$$

in which—

$$L = \mathrm{L}_0 + u\,G + \tfrac{1}{2}\,\pi - L_0$$

If we now compute the values of E by means of the preceding expression of tan E for each of the 24 values of λ given in Table VII, putting $E = 1.50$, and substitute them in the preceding expression of Δ, and compare the results with the 24 values of Δ in Table VII, we obtain 24 equations for determining the value of the unknown quantity L; and this being determined, each of the 24 values given by the preceding expression of Δ should agree with those in the table within the limits of the possible errors of observation. In this manner, we obtain $L = 71^\circ.3$. With this value of L, and the computed values of E for each of the 24 values of λ, we get the computed values of Δ in Table VII. The values of λ to be used in these computations are those of Table VII, corrected for the time from transit C, to which those in the table belong, to the time of high water, which, as shown in § 22, is $25^\circ.1$. It must be remembered, also, that in the values of $u\,t = \lambda - \frac{1}{2}\,\pi$, this corrected value of λ of Table VII must be used in both the expressions of M_1 and tan E preceding. With the value $\varepsilon = 1.50$, before determined, and the other known quantities in the preceding expression of M_1, we get, for the 24 values of $u\,t = \lambda - \frac{1}{2}\,\pi$, the 24 computed values of Δ in Table VII.

31. By comparing the values of M_1 and Δ in Table VII, computed from the preceding formula, with those which had been obtained from the differences of the observed times and heights of upper and lower transits, the differences between these values of M_1 and Δ are mostly those only depending upon the uneliminated errors of observation. In the comparisons of the two sets of values of Δ, a small systematic difference is discernible, with a maximum of about 2°. This, no doubt, depends upon small errors in Δ, as determined from observations, resulting, as has been stated, from the effects of the shallow-water tides not having been completely corrected for; for

an error of 2° in the epoch of a tide, with an amplitude of only about three inches in the mean, implies an error only equivalent to about 0.1 inch in amplitude. The result completely verifies the truth of the preceding theory of this singular tide of New York Harbor, as well as the correctness of all the formulæ used in the preceding development and explanation of it.

With the preceding values of A_0 and E, and the known value of u, we get, from the expressions of A and A' (§ 28),—

$$A = .214 \text{ ft. } (1 + .230 \times 1.5) = .288 \text{ ft.}$$
$$A' = .214 \text{ ft. } (1 - .230 \times 1.5) = .140 \text{ ft.}$$

32. The value of $E = 1.5$, determined from the lunar diurnal tide, enables us to determine the solar diurnal tide, which has not been deduced from the discussion of the observations. In the case of one harmonic component of the solar diurnal tide, the value of u is the same as in the lunar, and the two exactly coincide. The value of u for the other component, on account of the very slow motion of the sun in longitude, differs but little from it, and is .196 (*Tidal Researches*, § 28). Denoting, therefore, the amplitudes of the two solar components by a and a', and putting the ratio between the lunar and solar forces equal 0.45, we shall have—

$$a = .214 (1 + .230 \times 1.5) \times 0.45 = .130 \text{ ft.}$$
$$a' = .214 (1 + .194 \times 1.5) \times 0.45 = .124 \text{ ft.}$$

When the two components coincide at the times of the sun's greatest declination, we have a solar diurnal tide with an amplitude of $a + a' = .254$ ft., and at the time, or very nearly, of the sun's crossing the equator, a diurnal tide with an amplitude only of $a - a' = .006$ ft. The solar diurnal tide, therefore, sensibly vanishes when the sun is on the equator.

PRACTICAL APPLICATIONS.

33. We have now, in the preceding tables of average quantities, and the constants determined from them in the preceding pages, all the necessary data for constructing tables for the computation of a tidal ephemeris of the heights of high and low waters and the times of their occurrence. We shall give here, however, only tables for the high waters, since the heights and times of high water merely are given in the tidal ephemeris published by the Coast Survey. In constructing these tables, we shall neglect the most of the small inequalities of the second order, since these inequalities are always very small, and are especially so in New York Harbor, since the amplitude of the tide there is small, and these inequalities are proportional to the whole amplitude of the tide. Neglecting these numerous inequalities, and giving tables for high waters only, we shall be able to make the tables and the whole method of computing the tidal ephemeris very much more simple than that which has been given for the tides of Boston Harbor. In the latter case, a method of computing the tidal ephemeris as accurate as possible was needed for making accurate comparisons between theory and observation. The following tables and method being designed merely for computing a tidal ephemeris for practical purposes, the neglect of the small inequalities referred to above, which, in the case of New York Harbor, can rarely, in the aggregate, amount to more than one inch in the heights of the tides, or to more than one or two minutes in the times, can be of no consequence, especially as the abnormal inequalities of winds and changes of barometric pressure, which cannot be taken into account in the predictions of the tides, frequently amount to ten times these neglected quantities.

34. The following tables are so arranged as to include in the same table the inequalities in both the amplitude of the tide and the changes of mean level, and likewise the effects of the shallow-water terms, so far as they affect the heights and times of high water. They also include all the inequalities of a second order depending upon the same argument in the tables of single entry. The principal inequality of the second order in the lunitidal interval depends upon the moon's transit and parallax. This is an inequality of about three minutes at the maximum, and this has been taken into account by means of a table of double entry (Table I, Appendix).

By making the lunar parallax and declination the arguments in the tables, we are enabled to including a great number of terms of a second order of the inequalities which arise in developments into expressions with circular arguments. In this way, the effects of all the terms in the expression

of the lunar parallax are included in the tables having the parallax for an argument; and the effects depending upon the longitude of the moon's node are included in the tables having the declination for the argument. In these convenient arrangements, however, some slight sacrifices of theoretical accuracy have to be made; but they are too small to be of any consequence.

35. In the tables given in the Appendix for computing the tidal ephemeris,—

Arg. I is the apparent time of the moon's transit over the meridian of Washington next preceding the time of high water;

Arg. II is the moon's parallax one lunar day preceding the time of the moon's transit, used as Arg. I;

Arg. III is the moon's declination one lunar day preceding the time of transit, as in Arg. II;

Arg. IV is the moon's parallax 1.5 lunar days after the time of transit, used as Arg. I;

Arg. V is the moon's right ascension at the time of transit, as taken in Arg. I;

Arg. VI is the moon's declination 1.5 lunar days after the time of transit thus taken.

The mean height of sea-level used in the following tables is 4.45 feet, which is the average given for the last four years in Table V, and therefore corresponds to the zero-plane at the close of the series, supposing that it remained unchanged these four years.

DIRECTIONS FOR COMPUTING A TIDAL EPHEMERIS.

Directions for computing a tidal ephemeris will be best understood in connection with the example given in the Appendix. The column headed A, is the mean time of the moon's transit over the meridian of Washington, taken from page 330 of the American Ephemeris. The column a contains the equation of time for the time of transit, taken from page 324 of the Ephemeris. $A - a =$ Arg. I, omitting the days, is the apparent time of the moon's transit. Arg. II is the moon's parallax at the time of transit, obtained by interpolation from page 337 of the Ephemeris, and entered in the column one day in advance; that is, the parallax belonging to $1^d\ 3^h\ 57^m.6$ is entered in the next place opposite $2^d\ 4^h\ 40^m.7$, and so on; so that the parallax used is that belonging to the time preceding the time of transit by one lunar day. Arg. IV is the parallax, taken 2.5 lunar days in advance, as it is entered in the column headed Arg. II; that is, one and a half lunar days after the time of transit. This is obtained with sufficient accuracy from Arg. II by means of interpolation, taking into account first differences only. Arguments III and V are the moon's declination and right ascension at the time of transit, taken from page 6 of the American Ephemeris for Greenwich, adding 5^h to the time of Washington transit used as an argument, for reduction, approximately, from Washington to Greenwich time. Thus, for the first date in the example, in the column A add 5^h, and we have, approximately, $1^d\ 9^h$, corresponding to which, we get from the Ephemeris, page 6, the declination and right ascension in the columns headed Arg. III and Arg. V; but the declinations are placed one day in advance, as in the case of Arg. II. Arg. VI is Arg. III taken 2.5 lunar days in advance, as in the case of Arg. IV with regard to Arg. II. With Arg. I and Arg. II, take a from Table I; and with Arg. IV and Arg. V, take from Table II the parallactic and declination inequalities, denoted by b and c in the headings of the columns in the example. With the month as an argument, then take from Table II the annual inequality, and place it in the column headed d. The numbers in the table are for the middle of the months, and, for other parts, small corrections can be made by means of the differences. Then take the sums of $A + a + b + c + d + 19^h = S$, and enter them in the column headed S, leaving intermediate spaces for the interpolations to lower transits. The 19^h is composed of 12^h, to reduce the astronomical time in A to civil time, and of 7^h, which, together with the constants in the tables, make out $8^h\ 7^m.2$, the mean lunitidal interval. The column S, therefore, is civil time; and, when the hours exceed 12, the time is in the afternoon. The larger figures in Δ^1 and Δ^2 are the differences by means of which the interpolations are made. The interpolated numbers are obtained by adding $(\frac{1}{2}\Delta^1 - \frac{1}{8}{}^2\Delta)$ to the preceding number. The smaller figures in Δ^1 and Δ^2 are the two terms of the preceding expression used in the interpolation. The columns headed δ are the differences after interpolation. In these differences, the day and the half-day, or 12^h, are not written in the example of computation, but borne in mind in making the interpolations.

From the latter part of Table II, with Arg. V now take the effect of the lunar diurnal tide, and enter it in the column m; and, from Table IV, with the hour of transit as one argument and the month as the other, take the effect of the solar diurnal tide, and enter it in the column n. The sum of $m + n = s$ is then interpolated for the intermediate values belonging to the lower transit, and these, it must be borne in mind, must be taken with the contrary signs; that is, where s is added to S for upper transits, it must be subtracted for lower transits, and *vice versa*. In this way, the column headed *t. h. w.* is obtained, which, taken in connection with the days and hours of S, is the time of high water, the decimals of a minute being neglected.

In precisely the same manner are the accented quantities taken from the same tables, using the columns headed "Heights" instead of "Times", except that n' is taken from Table III instead of Table IV. We then enter $a' + b' + c' + d' + 5.00$ ft. $= S'$ in the column headed S', and then proceed with the interpolations for lower transits, and with the corrections for the effects of the diurnal tide, in the same manner as in the case of the times. The constant 5.00 ft., together with the constants in the tables, is the mean height of high water above the zero-plane. The final result, in the column headed *h. h. w.*, is the height of high water above the zero of the tide-gauge, as it stood at the close of the series of observations.

Of course, no tidal theory or tide-tables can take into account the abnormal meteorological disturbances of winds and changes of barometric pressure, which are frequently quite large, and differ very much in different ports for the same meteorological changes. The results obtained, therefore, by the preceding directions, although designed to be near approximations to the true times and heights of the tides in an undisturbed sea, will necessarily differ considerably from the observed times and heights in individual cases.

Very respectfully, yours,

WM. FERREL.

Capt. C. P. PATTERSON,
Superintendent of the United States Coast Survey.

APPENDIX CONTAINING PRACTICAL TABLES FOR COMPUTING THE HEIGHTS AND TIMES OF HIGH WATER.

TABLE I.

For obtaining the half-monthly inequalities in the height of high water and the lunitidal interval.

Moon's transit.		Inequality in height: Arg. I.	Inequality in the lunitidal interval: Arg. I and II.							
			Moon's parallax.							
			54°	55°	56°	57°	58°	59°	60°	61°
h.	*m.*	*Feet.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*	*m.*
0	0	1.00	25.8	25.4	25.0	24.6	24.3	24.0	23.6	23.2
0	30	1.01	21.0	21.0	20.9	20.7	20.6	20.4	20.2	20.1
1	0	0.97	16.6	16.6	16.7	16.8	16.9	17.0	17.0	17.1
1	30	0.90	12.6	12.8	13.0	13.3	13.5	13.7	14.0	14.4
2	0	0.82	9.0	9.4	9.8	10.5	10.9	11.3	11.7	12.0
2	30	0.75	6.3	6.8	7.3	7.9	8.4	9.0	9.5	10.0
3	0	0.67	4.0	4.6	5.3	6.0	6.6	7.3	7.9	8.5
3	30	0.59	2.2	3.0	3.7	4.5	5.2	6.0	6.7	7.4
4	0	0.52	1.3	2.0	2.8	3.6	4.4	5.2	6.0	6.7
4	30	0.46	0.8	1.6	2.4	3.1	3.9	4.6	5.4	6.3
5	0	0.38	0.4	1.2	2.0	2.8	3.6	4.4	5.2	6.1
5	30	0.28	0.1	1.0	1.8	2.6	3.4	4.2	5.1	6.0
6	0	0.20	0.6	1.4	2.3	3.1	4.0	4.8	5.7	6.6
6	30	0.14	3.3	4.0	4.8	5.5	6.2	7.0	7.7	8.4
7	0	0.11	9.0	9.4	9.8	10.3	10.7	11.1	11.5	12.0
7	30	0.12	18.0	18.0	18.0	18.0	18.0	18.0	18.0	17.9
8	0	0.17	27.8	27.3	26.8	26.3	25.8	25.3	24.8	24.4
8	30	0.26	36.0	35.1	34.2	33.3	32.4	31.5	30.6	29.7
9	0	0.36	41.5	40.4	39.3	38.2	37.1	36.0	34.9	33.8
9	30	0.48	43.2	42.0	40.8	39.6	38.5	37.3	36.1	35.0
10	0	0.62	42.2	41.2	40.2	39.2	38.1	37.1	36.1	35.0
10	30	0.75	39.5	38.6	37.7	36.7	35.8	34.9	34.0	33.0
11	0	0.85	35.4	34.6	33.8	33.0	32.2	31.4	30.6	29.7
11	30	0.94	30.7	30.1	29.5	28.9	28.3	27.7	27.1	26.5
12	0	1.00	25.8	25.4	25.0	24.6	24.3	24.0	23.6	23.2

TABLE II.

For obtaining the lunar parallactic and declinational inequalities and the annual inequality of the height and time of high water, and the effects of the lunar diurnal tide upon the same.

Moon's parallax.	Inequality in—		Moon's dec.	Ineq. in heights: Arg. III.	Moon's AR.	Ineq. in times: Arg. V.	Month.	Annual inequality in—		Effect of lunar diurnal tide on—			
	Heights: Arg. II.	Times: Arg. IV.						Heights.	Times.	Heights: Arg. VI.		Times: Arg. V.	
										☽'s dec.	Ineq.	☽'s AR.	Ineq.
° ′	Feet.	m.	°	Feet.	h.	m.		Feet.	m.	°	Feet.	h.	m.
54 0	0.00	22.5	0	0.32	0	13.2	Jan	0.33	31.0	0	0.00	0	+ 5.2
54 30	0.06	21.0	2	0.32	1	14.0	Feb	0.27	29.5	2	0.04	1	4.5
55 0	0.12	19.5	4	0.31	2	13.2	March	0.40	27.0	4	0.08	2	3.5
55 30	0.18	18.0	6	0.30	3	10.5	April	0.68	24.0	6	0.12	3	2.4
56 0	0.24	16.5	8	0.29	4	7.0	May	0.82	23.5	8	0.16	4	+ 1.1
56 30	0.30	15.0	10	0.28	5	3.5	June	0.76	24.0	10	0.20	5	— 0.4
57 0	0.36	13.5	12	0.26	6	0.9	July	0.66	25.0	12	0.24	6	1.8
57 30	0.42	12.0	14	0.24	7	0.0	Aug	0.66	26.0	14	0.28	7	3.0
58 0	0.48	10.5	16	0.21	8	0.9	Sept	0.65	28.0	16	0.32	8	3.9
58 30	0.54	9.0	18	0.18	9	3.5	Oct	0.63	29.5	18	0.35	9	4.7
59 0	0.60	7.5	20	0.15	10	7.0	Nov	0.46	30.5	20	0.38	10	5.3
59 30	0.60	6.0	22	0.12	11	10.5	Dec	0.23	31.0	22	0.41	11	5.5
60 0	0.72	4.5	24	0.09	12	13.2				24	0.44	12	— 5.2
60 30	0.78	3.0	26	0.05						26	0.47		
61 0	0.84	1.5	28	0.00						28	0.49		
61 30	0.90	0.0											

NOTE.—When the declination is south, or the right ascension more than 12*h*, the signs of the inequalities must be reversed. When the right ascension is more than 12*h*, the table is entered with the excess over 12*h* as the argument. The sign of the effect of the diurnal tide must be reversed for the high water immediately following the lower transits of the moon.

TABLE III.

For obtaining the effect of the solar diurnal tide upon the height of high water for every hour of the moon's transit, and the first of each month, expressed in hundredths of a foot.

Month.	Hours of moon's transit in astronomical time.																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan......	+25	+23	+20	+15	+10	+ 3	- 3	-10	-15	-20	-23	-25	-25	-23	-20	-15	-10	- 3	+ 3	+10	+15	+20	+23	+25
Feb.....	20	18	14	12	7	2	2	7	12	14	18	20	20	18	14	12	7	2	2	7	12	14	18	20
March...	+ 9	+ 8	+ 6	+ 5	+ 3	+ 1	- 1	- 3	- 8	- 6	- 8	- 9	- 9	- 8	- 6	- 5	- 3	- 1	+ 1	+ 3	+ 5	+ 6	+ 8	+ 9
April....	- 5	- 5	- 4	- 3	- 1	- 1	+ 1	+ 1	+ 3	+ 4	+ 5	+ 5	+ 5	+ 5	+ 4	+ 3	+ 1	+ 1	- 1	- 1	- 3	- 4	- 5	- 5
May....	15	14	13	10	6	2	2	6	10	13	14	15	15	14	13	10	6	2	2	6	10	13	14	15
June....	24	23	18	14	9	3	3	9	14	18	23	24	24	23	18	14	9	3	3	9	14	18	23	24
July....	25	23	20	15	10	3	3	10	15	20	23	25	25	23	20	15	10	3	3	10	15	20	23	25
Aug.....	20	18	15	12	7	2	2	7	12	15	18	20	20	18	15	12	7	2	2	7	12	15	18	20
Sept.....	- 9	- 8	- 6	- 5	- 3	- 1	+ 1	+ 3	+ 5	+ 6	+ 8	+ 9	+ 9	+ 8	+ 6	+ 5	+ 3	+ 1	- 1	- 3	- 5	- 6	- 8	- 9
Oct......	+ 5	+ 4	+ 3	+ 2	+ 1	+ 1	- 1	- 1	- 2	- 3	- 4	- 5	- 5	- 4	- 3	- 2	- 1	- 1	+ 1	+ 1	+ 2	+ 3	+ 5	+ 5
Nov.....	15	14	12	10	6	2	2	6	10	12	14	15	55	14	12	10	6	2	2	6	10	12	14	15
Dec ...	+24	+23	+18	+14	+ 9	+ 3	- 3	- 9	-14	-18	-23	-24	-24	-23	-18	-14	- 9	- 3	+ 3	+ 9	+14	+18	+23	+24

NOTE.—For lower transits, the signs must be reversed.

TABLE IV.

For obtaining the effect of the solar diurnal tide upon the time of high water for every hour of the moon's transit, and for the first of each month, expressed in tenths of a minute.

Month.	Hours of moon's transit in astronomical time.																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Jan......	- 6	-17	-24	-27	-29	-30	-30	-29	-27	-24	-17	- 6	+ 6	+17	+24	+27	+29	+30	+30	+29	+27	+24	+17	+ 6
Feb.....	5	12	18	22	24	24	24	24	22	18	13	5	5	13	18	22	24	24	24	24	22	18	12	5
March...	- 2	- 5	- 7	- 9	-10	-10	-10	-10	- 9	- 7	- 5	- 2	+ 2	+ 5	+ 7	+ 9	+10	+10	+10	+10	+ 9	+ 7	+ 5	+ 2
April....	+ 1	+ 3	+ 4	+ 5	+ 6	+ 6	+ 6	+ 6	+ 5	+ 4	+ 3	+ 1	- 1	- 3	- 4	- 5	- 6	- 6	- 6	- 6	- 5	- 4	- 3	- 1
May.....	4	9	13	16	19	20	20	20	19	16	11	4	4	11	16	19	20	20	20	19	16	13	9	4
June....	5	15	22	25	27	28	28	28	26	22	16	6	6	16	22	26	28	28	28	27	25	22	15	5
July....	6	17	24	27	29	30	30	29	27	24	17	6	6	17	24	27	29	30	30	29	27	24	17	6
Aug.....	5	12	18	22	24	24	24	24	22	18	13	5	5	13	18	22	24	24	24	24	22	18	12	5
Sept.....	+ 2	+ 5	+ 7	+ 9	+10	+10	+10	+10	+ 9	+ 7	+ 5	+ 2	- 2	- 5	- 7	- 9	-10	-10	-10	-10	- 9	- 7	- 5	- 2
Oct......	- 1	- 3	- 4	- 5	- 6	- 6	- 6	- 6	- 5	- 4	- 3	- 1	+ 1	+ 3	+ 4	+ 5	+ 6	+ 6	+ 6	+ 6	+ 5	+ 4	+ 3	+ 1
Nov.....	4	9	13	16	19	20	20	20	19	16	11	4	4	11	16	19	20	20	20	19	16	13	9	4
Dec.....	- 5	-15	-22	-25	-27	-28	-28	-28	-26	-22	-16	- 6	+ 6	+16	+22	+26	+28	+28	+28	+27	+25	+22	+15	+ 6

NOTE.—For lower transits, the signs must be reversed.

EXAMPLE OF THE COMPUTATION OF A TIDAL EPHEMERIS FOR THE FIRST PART OF JANUARY, 1876.

A			a	Arg. I.		Arg. II.		Arg. III.	Arg. IV.		Arg. V.	Arg. VI	a	b	c	d	a′	b′	c′	d′
d.	h.	m.	m.	h.	m.	′	″	°	′	″	h.	°	m.	m.	m.	m.	Feet.	Feet.	Feet.	Feet.
1	3	57.6	+ 3.8	3	53.8	55	25	− 16.2	56	58	22.7	− 1.4	2.6	13.6	9.5	31.5	0.53	0.17	0.20	0.38
2	4	40.7	4.3	4	36.4	55	57	10.6	57	45	23.5	+ 5.0	2.3	11.3	11.8	31.5	0.44	0.24	0.27	0.38
3	5	24.0	4.7	5	19.3	56	36	− 4.6	58	35	0.2	11.5	2.2	8.8	13.4	31.4	0.31	0.31	0.31	0.37
4	6	9.1	5.1	6	4.0	57	20	+ 1.8	59	25	1.1	17.4	3.8	6.2	13.9	31.4	0.19	0.40	0.32	0.37
5	6	57.4	5.6	6	51.8	58	10	8.3	60	10	2.0	22.5	9.8	4.0	13.2	31.4	0.12	0.50	0.29	0.36
6	7	50.5	6.0	7	44.0	59	1	14.6	60	44	2.9	26.3	21.6	2.2	10.8	31.3	0.14	0.60	0.23	0.36
7	8	49.3	6.5	8	42.8	59	49	20.3	61	4	3.9	28.1	33.0	1.3	7.3	31.3	0.30	0.70	0.15	0.36
8	9	53.7	6.9	9	46.8	60	30	24.8	61	4	5.1	26.6	35.6	1.3	3.2	31.3	0.56	0.78	0.07	0.35
9	11	1.3	7.3	10	54.0	60	58	27.7	60	42	6.3	25.0	30.3	2.2	0.7	31.3	0.83	0.84	0.01	0.35
10	12	8.4	7.7	12	0.7	61	9	28.4	60	4	7.4	20.3	23.0	2.8	0.4	31.2	0.99	0.86	0.03	0.35
11	13	11.0	8.1	13	2.9	60	56	26.7	59	13	8.5	14.6	17.0	5.3	2.0	31.2	0.96	0.83	0.02	0.34
12	14	7.9	8.5	13	59.4	60	27	23.0	58	15	9.6	8.5	11.9	8.2	5.0	31.2	0.84	0.77	0.10	0.34
13	14	59.1	8.9	14	50.2	59	41	17.6	57	17	10.5	+ 2.0	8.3	11.2	9.0	31.1	0.70	0.68	0.19	0.34
14	15	45.9	9.3	15	36.2	58	45	11.7	56	22	11.4	− 4.3	5.5	15.4	11.5	31.1	0.58	0.57	0.26	0.33
15	16	29.9	+ 9.6	16	20.3	57	45	+ 5.2	55	34	12.2	− 10.3	3.9	17.8	13.3	31.0	0.48	0.45	0.30	0.33

S			Δ¹	Δ²	δ	m	n	s	t. h. w.	S′	Δ′	Δ″	δ	m′	n′	s′	h. h. w.
d.	h.	m.	m.		m.	m.			m.	Feet.							Feet.
1	23	54.9	+ 42.7		+ 21.4	+ 5.4	− 2.9	+ 2.5	57	6.28	+ .05	− .08	+ .03	− .03	+ .10	+ .07	6.35
2	12	16.3	21.4		21.4			2.5	14	6.31	+ 1	+ 1	.02			.11	6.20
3	0	37.6	42.2	− 5	21.2	5.5	3.0	2.5	40	6.33	− .03	− .08	.00	+ .10	+ .04	.14	6.47
3	12	58.8	21.1	+ 1	21.0			2.2	57	6.33	0	+ 1	− .03			.19	6.14
4	1	19.8	44.6	+ 24	22.0	4.9	3.0	1.9	22	6.30	.02	+ .01	.01	.23	.00	.23	6.53
4	13	41.8	22.3	− 3	22.6			1.6	40	6.29	0	0	.01			.26	6.03
5	2	4.4	51.4	+ 68	24.9	4.3	3.0	1.3	6	6.28	− .01	.01	.00	.32	− .04	.28	6.56
5	14	29.3	25.7	− 8	26.5			1.0	28	6.28	0	0	− .01			.30	5.98
6	2	55.8	60.9	+ 95	29.2	3.5	2.9	0.6	56	6.27	+ .06	.07	+ .02	.42	.10	.32	6.59
6	15	25.0	30.4	− 12	31.7			+ 0.2	25	6.29	− 1	− 1	.04			.33	5.96
7	13	56.7	65.5	+ 46	32.1	2.5	2.7	− 0.2	56	6.33	.18	.12	.08	.48	.14	.34	6.67
7	16	28.8	32.7	− 23	33.4			0.7	29	6.41	− 2	− 1	.10			.32	6.09
8	5	2.2	62.9	− 26	31.7	+ 1.2	2.4	1.2	1	6.51	.25	.07	.11	.49	.19	.30	6.81
8	17	33.9	31.4	+ 3	31.2			1.7	36	6.62	− 3	− 1	.14			.29	6.33
9	6	5.1	60.7	− 22	30.6	− 0.5	1.7	2.2	3	6.76	.27	+ .02	.14	.49	.22	.27	7.03
9	18	35.7	30.3	+ 3	30.1			2.5	38	6.90	− 3	0	.13			.25	6.65
10	7	5.8	60.0	− 07	30.1	2.2	− 0.6	2.8	3	7.03	+ .14	− .13	.09	.47	.25	.22	7.25
10	19	35.9	30.0	+ 1	29.9			2.8	39	7.12	− 2	+ 2	.05			.19	6.93
11	8	5.8	61.8	+ 18	30.7	3.4	+ 0.7	2.7	3	7.17	− .02	.16	+ .01	.40	.25	.15	7.32
11	20	30.5	30.9	− 2	30.0			2.7	39	7.18	0	+ 2	− .03			.11	7.07
12	9	6.5	58.7	− 31	29.7	4.4	1.8	2.6	4	7.15	.10	.08	.04	.30	.22	.08	7.23
12	21	36.2	29.3	+ 4	28.0			2.6	39	7.11	+ 1	+ 1	.06			+ .04	7.07
13	10	4.2	54.5	− 42	27.7	5.1	2.4	2.7	1	7.05	.14	.04	.07	.17	.17	.00	7.05
13	22	31.9	27.2	+ 5	26.8			2.7	35	6.98	+ 2	0	.07			− .05	7.03
14	10	58.7	51.7	− 28	26.2	5.4	2.7	2.7	56	6.91	.17	.03	.08	+ .04	.14	.10	6.81
14	23	24.9	25.8	+ 4	24.5			2.7	28	6.83	+ 2	0	.09			.15	6.98
15	11	49.4	46.5	− 52	23.8	5.5	2.8	2.7	47	6.74	− .18	− .01	.09	− .09	.10	.19	6.55
16	0	13.2	+ 23.2	+ 6	+ 22.7			2.5	16	6.65	+ 2	0	− .09			.23	6.88
16	12	35.9				− 5.1	+ 2.8	− 2.3	34	6.56				− .21	− .06	− .27	6.29

APPENDIX No. 13.

REPORT ON THE TRANSIT OF VENUS EXPEDITION TO JAPAN, BY GEORGE DAVIDSON, ASSISTANT IN THE UNITED STATES COAST SURVEY.

UNITED STATES COAST SURVEY SERVICE,
SUBOFFICE, SAN FRANCISCO.

DEAR SIR: In compliance with your request, I make the following report to you in relation to my work on the Transit of Venus Expedition to Japan in December, 1874.

I was ready to leave San Francisco by the second steamer of July, but, in accordance with your instructions to leave a plan of operations for all the parties on this coast during my absence, I was detained until the end of August, and reached Yokohama on the 24th of September. This delay compelled the abandonment of my project to observe the transit from a high mountain and in a locality where the chances for good weather were the greatest, and I determined to occupy a station at Nagasaki, where I could immediately connect with one end of the cable between Nagasaki and Wladivostok, for the determination of the telegraphic difference of longitude. The organization of the party was as follows: Prof. George Davidson, United States Coast Survey, chief astronomer, in charge of the party; Mr. O. H. Tittmann, United States Coast Survey, first assistant astronomer; Mr. W. S. Edwards, United States Coast Survey, second assistant astronomer; Mr. S. R. Seibert, United States Treasury Department, chief photographer; Mr. H. E. Lodge, Boston, first assistant photographer; Mr. F. H. Williams, Boston, second assistant photographer; Mr. Uyeno, of Nagasaki, third assistant photographer; Mrs. George Davidson, recorder; Master George F. Davidson, recorder. The three last named were in addition to the original organization, as I was too short-handed.

To the Japanese government I had proposed that several of the younger Japanese officers or students should accompany my party to witness the operations and study the methods and means employed in such work. The following gentlemen were appointed to accompany me: Lieut. K. Otomo, Imperial Japanese Navy; Midshipman K. Isono, Imperial Japanese Navy; Mr. T. Magome, Mombusho, Tokio. It was also arranged that Prof. David Murray, LL.D., Chief Councillor of the Educational Department of Japan, and Mr. Y. Hatakeyama, director of the Imperial College, should join the party December 1. Previous to that date, Capt. Narvo Yoshi Yanagi, Chief of the Bureau of Hydrography of the Navy Department, came from Tokio to witness the transit and longitude-experiments. Captain Yanagi is esteemed one of the most learned men in Japan.

Messrs. Yanagi, Murray, Hatakeyama, and Magome were required by their government to make special reports of the observations of our work; and from Captain Yanagi I received authority to procure for his department the instruments necessary for a small observatory at Tokio.

Through the kindness of Dr. Murray, I readily obtained the necessary authority from the government to examine and locate my station in any part of the empire, and to use the telegraphic lines for the business.

I arrived at Nagasaki October 6. Here the cable connects with Wladivostok and the southern parts of China. The previous three months had been characterized by continuous rains and heavy typhoons, one of which was very disastrous; but the weather seemed changed for the better.

After an examination of the hilly country immediately surrounding the bay upon which Nagasaki is situated, I selected a steep hill, 850 feet above the bay and about one mile south of the southern part of the town. I obtained permission from Miyagawa, Kenrei of Nagasaki district, to open a road to the top of the hill. The records contain the detailed description of the locality, and the chart shows its general relation to the bay of Nagasaki.

I put eighty-five men at work upon this road under the direction of Messrs. Tittmann and Edwards, and so soon as it was completed the houses and instruments were carried up. Piers for the transits and equatorial were built, and the iron piers for the photographic apparatus placed in position. The utmost care was exercised in building the foundations.

Although my instructions contemplated the execution of the telegraphic work after the transit, I cheerfully assented to the request of Professor Hall, at Wladivostock, to undertake it in advance, as otherwise the lateness of the season might cause him to be frozen in all winter.

For reasons not necessary to enumerate, I selected a transit-station for this longitude-work in the ground occupied by the telegraph company. I was informed that no arrangement had been made with the company for this work and no plan of operations had been proposed or agreed upon. Upon representing the whole matter to Mr. Th. Russell, the manager of the Great Northern Telegraph Company, he promised me the free use of the cable and placed me in communication with Mr. Carl Nielson, the electrician. I urged upon him the advantages of sending the clock-signals through the cable; and upon examining the instrumental connections and methods of work he reported favorably, and I was enabled, through the insulated armature of the clock-helix, to break circuit directly on the main line. But as the clock-signals were too short for transmission, the armature was held back at certain definite breaks in each minute. With more time and additional means I should have been able to lengthen the break through the instrument itself.

Of course, there were many little incidental difficulties in the way; but within ten days three nights were obtained wherein several hundred clock-signals were successfully sent and received from each station. I should have preferred two nights more, but Professor Hall expressed himself satisfied.

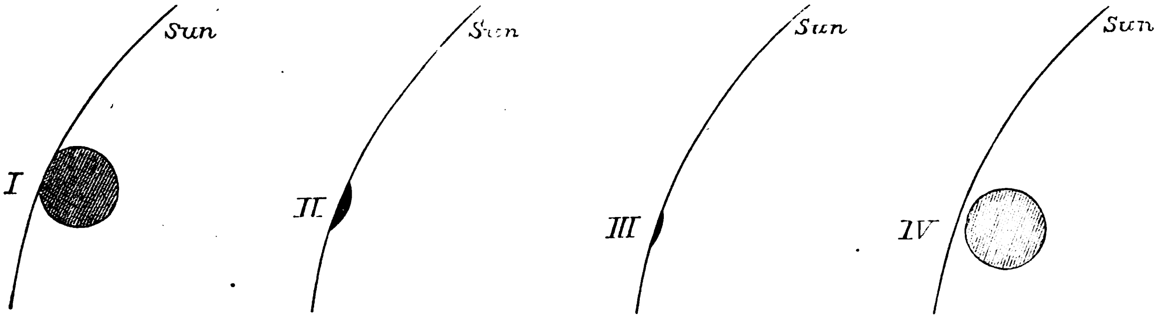
Mr. Russell, on behalf of the company, gave me the use of the line for one or two hours each night; and Mr. Nielson, when not on duty, gave his time wholly to our assistance. To the other gentlemen of the company we are also indebted for kind assistance in our operations. The telegraph longitude-work at this station was done with the United States Coast Survey meridian-instrument No. 2 (Davidson's) by Würdemann, and the double-pen chronograph 4848, and relays used by me in the San Francisco-Cambridge longitude-work of 1869 by the Coast Survey. Without these duplicates, I should have been compelled to execute this work after the transit.

The operations were completed on the 7th of November, and on the 8th I transferred all my time to the transit of Venus station.

Subsequently, this telegraph-station was connected with the transit of Venus station by triangulation, which also embraced the French transit station; but Professor Janssen never made any request to connect our stations, &c.

Up to November 14, fifteen observations of occultations of stars by the moon were made to compare with Pekin, but there was a blank in the list furnished from that date to December 2. However, I soon found the labor of the day and the regular work of preparation, practice, and observing was as much as could be done.

In order that I might be familiar with the phases of Venus, I had large painted boards placed on the Meridian Hill, three miles to the north of the transit-station. These phases were to repre-



sent the cusps (I); Venus when 40 seconds on (II); Venus when 10 seconds on (III); Venus when 40 seconds after second contact (IV). These were made of a size to show Venus as she would

really appear in the telescope. I recorded the practice upon these objects in the regular "day-book", observing upon them whenever practicable in all sorts of weather.

The regular observations for latitude and time were made by Mr. Tittmann, assisted by Mr. Edwards. Some delay was occasioned in this work by discovering that the levels of the Stackpole transit-instrument 1507 were useless from inferior workmanship; but, fortunately, I had the United States Coast Survey meridian-instrument with extra levels, which, after much trouble, I fitted in the transit.

I determined the value of the micrometer of this instrument, and also the equatorial intervals. Mr. Edwards determined the inequality of the pivots of the transit-axis, which was found exceptionally large.

The photographic apparatus was in good working order early in November, but for nearly two weeks there was not sufficiently clear weather for drill and practice. Upon the first favorable day, experiments were made for the best focus, and satisfactory results gave us a focus one inch shorter than that assigned to the lens. After this adjustment, the lens and reticulated plate never required changing.

The value of the level-scale on the reticulated plate, and that of the engineer's level, were determined by Mr. Tittmann. For the quick photographs proposed near I and IV contacts, I had made frames for holding half a dozen plates, each to obtain half the sun's disk. It would give six pictures per minute, but with proper mechanical means would give twelve pictures per minute. Mr. Seibert devised a method of getting a small part of the sun's border and the center, and to this I added means to get the electrical record; by this arrangement we could get a photograph every second. Messrs. Lodge and Williams efficiently aided all these preparations.

To make this branch of the transit labors a success, I directed Mr. Seibert to spare no means for its accomplishment. The observatory was enlarged, photographic material was procured, and additional photographers for the day of transit.

Upon the arrival of Dr. Murray, he cheerfully assumed the duty of recorder in the photographic room, besides assisting in other operations.

Everything was in good working order before December, and I felt that, so far as the means at our disposal were concerned, nothing had been overlooked or slighted.

The instructions had been carried out as systematically as practicable. The only deviation I made was in not taking down the heliostat every night of transit-work and directing the middle transit-thread on the reticulated plate before and after testing transits. The very act of removing and replacing such a heavy and unwieldy mass was, in my judgment, risking the safety of the reflector, and was nearly sure to jar the iron pier, if anything would. But the transit was always referred to the meridian-mark before the examination of the photographic-plate adjustments, and every evening and morning it was referred to the mark, so that we must know its deviation from the meridian very closely.

Notwithstanding my being in readiness, we had many annoyances to hinder uniformly smooth results, in the character of the instruments.

With the heliostat I had constant trouble, and was compelled to alter it and to clean it several times.

The chronograph ran irregularly in spite of attention and care, and was a source of constant annoyance with its frightful noise; but on the day of transit both chronographs were running well.

The spring governor of the equatorial broke, and no spare springs had been furnished with it; no instrument-maker was to be found in Nagasaki, and I took the instrument apart and replaced the broken spring. After running a short time, I had to take it apart and clean a second time; then the second spring broke, and again I replaced it, obtaining my springs from a Chinese watch-dealer. After more trouble from the spring, and another cleaning, I got it running well about two weeks before the transit.

The value of the screw of the double-image micrometer I determined by the transits of Polaris. And here it may be mentioned that there were several nights when the equatorial with the double-image micrometer and highest power would not show the companion of Polaris; and at all times the star was irregular and deformed.

Whenever the sun was visible I examined it, to judge of the general character of the limb and of the spots, with reference to their apparent sharpness of definition and steadiness, and for the faculæ, in comparison with my observations upon it in the Sierra Nevada in the summer of 1872. The conclusions from those observations are fully verified and confirmed.

A few days before the 9th, the weather was thickening—the nights were partially clear, the days heavy and threatening.

On the 8th, I obtained good transits for time, and repeated them at 4 a. m. on the morning of the 9th. Suddenly, the clear bright starlight morning was wholly covered with clouds, that grew denser until sunrise, and continued after it.

About 8 hours a. m. all the adjustments of the photographic apparatus were examined, the distance between the objective and reticulated plate measured, and soon after, through a break in the clouds, the reversed photographs were successfully made. Then the weather changed; two strata of clouds were seen to form, an upper stratum of cirrus and cirro-stratus forming a tolerably homogeneous screen; below that, and resting on the mountain-top, two or three miles south of us (and 1,950 feet elevation), was a dense stratum of cumulo-stratus coming up from the southward with slow, steady movement.

At 9.30 a. m., this lower stratum became dense and destroyed our hopes; but about 10 minutes after 10 o'clock a break occurred in it, and the sun was visible through the upper stratum with variable distinctness. At intervals it was too bright to observe with the unprotected eye at the equatorial, and, unfortunately, the shades of colored glasses were too few, and at every change had to be unscrewed, &c. I had an extra set furnished by the Coast Survey, but on preliminary examinations three had been cracked by the sun's heat.

I used the lightest shade furnished with the instrument (not the thin ones), and when I commenced steady watching, about two minutes before the predicted time (so as to include the time of the English prediction and to watch if Venus were visible off the sun's limb), the outline of the sun was moderately steady, yet not sharply cut and defined; and I would have liked a great deal more light.

As I kept up the beat of the chronometer, I felt sure that the predicted time was long passed, when the clouds suddenly thickened, and the faintest outline of the sun was visible; yet I had no time to unscrew the colored glass, and before I could have done so the sun's limb brightened, and the limb of Venus was seen just entered upon the sun at the exact spot which I had been steadily watching for over three minutes. From my practice with the artificial Venus I judge the planet was two seconds on at the time noted; at any rate, Mrs. Davidson made the record of the time I announced, with the necessary remarks. About 7 or 8 seconds thereafter I called to the photographers to commence.

The sun's limb was quite unsteady just before the first contact, and at the brightest intervals I could not see any approach of Venus nor any different indications at the point of contact other than existed at adjacent parts of the limb at which I occasionally glanced.

The epoch noted after the first contact was 1^m 36^s later than the predicted time.

Mr. Tittmann was observing with the Coast Survey Hassler telescope of 3.1 inches aperture, and when I called out to the photographer, he noticed that Venus was already on the sun's limb, and then noted the time. Captain Yanagi, with the United States Coast Survey reconoitering telescope No. 35 of 1½ inches objective, took his eye from his instrument as if he had not seen the planet.

I prepared to obtain measures of the distance of the planet from the sun's limb, as I had practiced, but, though visible, it was then too faint to admit of observations of precision. I tried again, as I had before the first contact, to observe with the unshaded eye, but sudden openings in the clouds rendered this too full of risk to my eyesight.

When about half the image of the planet had entered upon the sun's disk, the images lengthened, and I made fourteen micrometer-readings of the cusps under varying conditions of brightness. The cusps were not so bright as I could desire; a lighter shade-glass or other means for regulating the amount of light would have enabled me to get more certain and more numerous measures.

When near the second contact, I turned the double-image micrometer to zero for that observation.

Second contact.—This I obtained as well as such an observation can be made, and although I think

it was noted exactly, yet I feel satisfied that it has not an error of 2 seconds; it occurred about 2 minutes after the predicted time. There was no black-drop or true ligament or band, only slight disturbance of the limbs that prevented such a sharp separation as I had observed in the total solar eclipse of 1869 in Alaska.

But this disturbance was exactly similar to what I have been accustomed to meet with in twenty-nine years' experience on the Coast Survey at small elevations. It was similar to the disturbance that I had noticed in the artificial Venus; but upon this subject I will add an appendix.

Mr. Tittmann reports that he observed the second contact well. The sun was seen through the haze or thin clouds of the upper stratum, and the limb was not disturbed. The line of light broke clearly and in an apparent true continuation of the limb of Venus. He reports that when he took his eye from the telescope to catch the tens of seconds on the chronometer, Captain Yanagi called out "time" to his assistant, thus noting it about four seconds later than Mr. Tittmann.

After the second contact, I commenced measures of the separation of the limbs of the planet and sun, and with varying phases of brightness and unsteadiness until the images were too faint. I obtained seventy-eight micrometer-readings.

I had mounted the United States Coast Survey meridian-instrument No. 2 to observe the passage of the sun and Venus at meridian transit, and also arranged for Mr. Tittmann to observe the difference of declination of the upper limb of the sun and of the limbs of Venus in transit-instrument No. 1507.

Near culmination, the sun was partially obscured, and I used the light shades of the sextant, giving a light-orange image of the sun. The record was made on the fillet of the Coast Survey chronograph 4848 under the watching of George F. Davidson, and I observed the first limb of the sun over 9 threads, the first limb of Venus over 8, and second limb over 8 threads, and the second limb of the sun over 6 threads.

Mr. Tittmann made nineteen micrometer-readings of the sun's apparent upper limb and the upper and lower limbs of Venus, the time being noted by Mr. Edwards.

Clouds again intervened; but at ten minutes after meridian I commenced measuring the diameter of Venus with the double-image micrometer with varying phases of visibility. In this work I obtained forty-four micrometer-readings, and good results. Mr. Tittmann made nine measures and Dr. Murray six, when the clouds obscured the sun completely.

The observations for the meridian passage of the sun, and of Venus when projected thereon, for differences of declination and for the diameter of the planet, are not mentioned in the instructions of the commission.

The clouds increased, and nothing now seemed possible. There was a slight break when Venus was one diameter from the third contact; then more clouds.

Third contact.—At the third contact there was an opening in the clouds, and ten or fifteen seconds before contact I saw the clear separation of the limbs with little or no unsteadiness—better even than at second contact; no ligament or band—when clouds suddenly covered it at the time of contact, and again broke away just after contact. But I felt that contact had not occurred more than five seconds, and noted the time of the reappearance of brightness, with proper remarks. There was a clear, sharp outline; no disturbance. The sharp points of the cusps were almost touching, and were very delicately-pointed objects. This epoch is only eighteen seconds from the predicted time. For this observation I was using the unprotected eye, and in the sudden gleams of brightness was almost compelled to desist. Mr. Tittmann observed with the unshaded eye, and noted the contact, but recorded that "clouds passing interfered with the exactness of the determination, but apparently the clouds caused the only uncertainty. Observer cannot form an estimate of the error of his observation."

After the third contact there was a slight opening in the clouds, and without sunshade I tried to get measures of the cusps, but succeeded in obtaining only three micrometer-readings with cusps' points.

Fourth contact.—At the time of the fourth contact the sky was hidden by dense clouds, and about 4 p. m. rain commenced.

During the observations at the equatorial I was assisted by Mr. Tittmann, who noted the times for the micrometer-measures. Mrs. Davidson and George F. Davidson assisted in recording other observations and attending to the chronograph.

PHOTOGRAPHIC WORK.

After I notified the photographers to commence, the plates for frequent exposures near first contact were run through, but no indentation of Venus is exhibited. This was when I failed to get measures for the cusps. When the sun came out sufficiently bright for me to observe, impressions were obtained, and the negatives were exposed whether there was sun or clouds; of course, many plates show nothing whatever; but by this plan views were obtained at intervals when there was an opening of a minute or two.

Had there been a clear day, the operations were so systematic and consecutive, from my employment of extra photographers—Japanese—that not less than four hundred plates could have been made.

About one hundred and sixteen plates were exposed up to the time when the sun wholly disappeared, and probably one-half of that number furnish as fair photographs as could be obtained under the circumstances, and with collodion films.

Mr. W. S. Edwards remained at the heliostat throughout the day to direct it in case of derangement. He had been well practiced to have taken Mr. Tittmann's or my place in case of our illness or of accident.

Time-observations.—At dark, after the transit, there was a narrow break in the rain-clouds for half an hour or more, and I fortunately succeeded in getting a good set of transit-stars for time. Then the night shut in, thick and raining.

Having been informed by the Secretary of the Commission that the funds of the Commission were low, that the telegraph-work hence to Melbourne was abandoned, and that I should close operations as soon as practicable, I made my preparations accordingly; but carried on photographic experiments for one week longer, as instructed.

The instruments were dismounted, and such as were ordered home were shipped, while others were deposited in the United States naval storehouse, as directed; but a receipt for the same was refused me by the United States naval storekeeper.

The work of preparation and observation had given me a fair opportunity for judging of the capacity of the instruments and methods, outfit, and *personnel* for working, and I proposed to the Commission to make a special report thereon. Some of my views of the instruments have been embodied in my general report to you.

On behalf of the members of my party I can speak with freedom, because there has been no jar, want of harmony, or shrinking from duty, and they gained the respect of the Japanese officials and people.

And it is a pleasant duty to report my gratitude and hearty thanks to the Japanese authorities for assisting my labors and intercourse with the people, for affording me use of the government telegraph from Nagasaki to Tokio for subsequent telegraphic longitude-work, and for assigning officers of rank, position, and qualification to accompany the expedition and assist in the final work, and to report upon its appliances and methods, &c.

In connection with the transit-work, a short series of magnetic observations was made to include the declination, horizontal force, and inclination.

And to connect the telegraph and transit stations, as well as to include the French station, a short base was measured, signals erected for triangulation, and azimuth-observations made sufficient for the purpose.

The records of all the transit-work and the day-books were duplicated and forwarded to the President of the Commission, before my leaving Nagasaki.

You will recollect that I appealed to you and to the President of the Commission for permission to determine the telegraph difference of longitude between Nagasaki and Tokio, at the expense of the Commission or of the Coast Survey.

At the request of Captain Yanagi, Dr. Murray, and others, and the promise of their assistance, I determined to bear the cost of this undertaking myself after all the transit-work was done. On their return homeward, Messrs. Tittmann and Edwards voluntarily offered to give their services at Tokio, instead of taking a short leave of absence which I had granted them.

For this work, a small observatory was erected in the extensive grounds of the Imperial Navy Department at Tokio, and a loop of the main telegraph-line was run from the telegraph main station. A loop was also run into the Mexican transit of Venus station at Yokohama, whereby Señor Don Dias Corrubias was enabled to receive my signals passing between Nagasaki and Tokio; and some of the details of my plan were made to accord to his wishes, as he was not in reality prepared with instruments for this work.

My signals passed through the main line at Kobi (Hiogo), where the second French station was located; but Professor Janssen was engaged for several weeks in determining the telegraphic difference of longitude between Nagasaki station and Kobi.

Every assistance was rendered to the party at Tokio, by Captain Yanagi, Chief of the Bureau of Navigation, and by Mr. Tanaka, Vice-Minister of Education, seconded by Mr. Morris, the Chief of the Telegraph-lines.

At Nagasaki, I received the hearty support of the Japanese superintendent and his native and European assistants. For recorder in this work I had the services of my son, George F. Davidson.

This hearty co-operation at both ends of the line, and moderately good weather, enabled me to obtain the transmission of clock-signals on seven nights between December 20, 1874, and January 2, 1875; with a field-computed result of $39^{m}\ 30^{s}.2$ for the difference of longitude instead of $39^{m}\ 40^{s}$ from the charts. This result I communicated to Captain Yanagi. Want of time has prevented my further reduction of this special work.

In this work, the weakness of the single-pen chronograph was made evident. A two-pen chronograph was used at Tokio, and a one-pen chronograph at Nagasaki. Upon two nights the Tokio clock broke so nearly coincident with mine that I could have gotten only an approximate result if I had not resorted to unusual expedients. Had a mean-time chronometer been available at one end of the line for the transmission of signals this trouble would have been obviated. My letter to you of January 14, 1875, mentions this and correlative matters.

While I was engaged in this work, Dr. Valentine, the chief of the German transit-party at Chufoo, China, arrived with chronometers on a German man-of-war for the determination of the difference of longitude between that station and Nagasaki. I gave him the use of my observatory when I should finish; but before that he compared with my chronometer for time. He did not move his chronometers from the vessel, but compared his pocket-chronometer with my observing-chronometer and then compared with the chronometers on the vessel. During the Tokio telegraph longitude-work we observed for personal equation.

I may here mention that upon the twenty-four-day voyage from San Francisco to Japan I made observations for magnetic variation, and in midocean the steamship was swung to correct my observations. Having no special instruments, I used the ordinary Schmalkalder compass. I also observed the dip daily; but, unfortunately, the axis of the observing-needle was broken the day before arriving at Yokohama.

OBSERVATIONS AT GREAT ELEVATIONS.

Before closing this report I desire to add a few words of my experience on the subject, of direct interest in the transit of Venus observations.

The judgment which I expressed about four years since of the importance and necessity of great elevations from which to make astronomical observations of precision, and subsequently, of the importance of observing the transit of Venus at great elevations (Special report and letter to the late Superintendent), was amply confirmed by my experience at Nagasaki.

At no time whatever had I been able to see with the Clark 5-inch No. 862, the limb, spots, penumbræ, faculæ, &c., of the sun with the same definiteness with which I daily observed it with the 3-inch Hassler, and a smaller telescope, on the Sierra Nevada at an elevation of 7,250 feet. I did not see a sharp border to the sun at Nagasaki up to January 4, 1875 (elevation 850 feet); was not able to trace the apparent inflowing toward the centers of the sun spots; and did not see the faculæ on any part of the sun. The limb of the sun was always blurred and unsteady.

On some nights the seeing was occasionally almost as good with this equatorial as with the Hassler on the Sierra; the serrations of the moon's limb and all the irregularities were well defined;

the border was exhibited with sharpness, and the fine points of the cusps were generally good objects.

The division of Saturn's rings was better here upon one or two nights with the Clark 5-inch than on the Sierra with the Hassler 3-inch, according to my recollections of the latter. So was the companion of Polaris at times, when I used the highest-power astronomical eye-piece.

Black drop, &c.—Having also expressed the conviction that the ligament, or black drop, of Venus was due to the same cause that produces Baily's beads, I am induced to give you a short account of my experiments before the transit of Venus.

Referring to the rough sketch already given to illustrate the artificial Venus on Meridian Hill, at Nagasaki:—these were made of the same size as the planet would actually appear in the telescope, and I practiced upon the different measures under nearly all conditions of weather, and made the record as if it were actual transit-work. In these experiments I experienced appearances such as occur to us almost daily in the geodetic work of the survey, and which in astronomical observations have been designated the "black drop," &c.

Upon some cloudy days, when the atmosphere was quiet, the outlines of the artificial Venus were comparatively sharp and steady; but when the sun shone out fiercely after a rain the outlines were confused and the objects unfit for observation. Early in the morning or late in the afternoon was the period when the objects were best suited for good work. When they were very unsteady and confused the border of the sun and the spots of the sun were also unsteady, boiling, and blurred and unfit for observations of precision. After such a day the moon frequently had a confused border and the ragged edge was ill defined and unsteady.

I had two meridian-marks for the transit-instrument near the artificial Venus, and on one of them was a board pierced with several holes. Under ordinary circumstances, the atmosphere was so unsteady, and the mark apparently so unsteady, that the holes could not be distinguished; but when the atmosphere became steady so that the artificial Venus and sun were moderately good objects for observation, then the holes in the meridian-mark could be seen distinctly. During the state of unsteadiness the sides of the adjacent holes were in fact apparently connected by the so-called ligament.

Lest there be doubt about that effect of the unsteadiness, I may mention that in my experience in geodetic work on the Pacific coast I have sometimes had my signal, as seen from certain directions, apparently almost touching a light-colored tree (say a dead, barked tree) near it. Whenever the atmosphere was steady, there was no doubt in the observer's mind about the separation of the two objects, but whenever the atmosphere became unsteady the two objects would become so confused as to apparently coalesce and separate throughout their lengths, and also join and separate in parts of their lengths. Again, poles standing out clear of surrounding objects become, when the atmosphere is unsteady, unusually diffused and broad, and frequently they can be seen flying away in parts as the unequally disturbed (refracted) atmospheric waves break up the image. Similar phenomena are seen with heliotropes, and especially when the objects are much elongated vertically. A similar phenomenon is exhibited by objects on the bottom of shallow water whose surface is greatly agitated by the wind.

What I witnessed in the experiments with the artificial Venus and sun I have experienced through thirty-two years' work. And on the 9th of December similar appearances, in a moderate degree, were exhibited between the limbs of Venus and the sun.

There were to me no new phenomena, although I was acutely alert to detect such, and I had no more difficulty in deciding than I have daily in geodetic work, or in transits of the sun or moon. There was a slight disturbance between the limbs of the sun and Venus exactly similar to the disturbance in the artificial Venus and sun, and of the same character that gives rise to the Baily's beads, and to the confusion of the images of double stars upon nights when the atmosphere is unsteady. There was ~~a~~ no ligament at this station as depicted and described by some of the observers of the transit of Venus of 1761 and 1769; and even reported by observers at Yokohama, in 1874. Certainly there was no such phenomenon as black drop. Nor was there to my vision any distortion of the planet's disk.

At the third contact, or rather about 5 or 10 seconds after it (for a cloud hid the actual contact),

the sun and planet were observed without colored glass; the atmosphere was then quite steady (threatening rain), and the cusps were very sharply defined. During these observations, I was observing through two strata of clouds, the upper one of which seemed to prevent the passage of heat-rays so that the lower body of air was not disturbed, *i. e.*, unequally and irregularly refracted. I had a somewhat similar experience in observing the total solar eclipse of August, 1869, in Alaska; the day was cloudy and at times rainy, the atmosphere was exceptionally quiet, and the disappearing limb of the sun at totality (seen through a rift in the clouds) was a line of the sharpest, clearest character, without a wave or a break in it. (*Vide* report to the Superintendent.)

In conclusion, from these and other observations and experiences, I have no hesitation in saying that all the phenomena of black-drop, ligament, &c., between Venus and the sun, as well as the phenomena of Baily's beads at total solar eclipses, are due to the unsteadiness of the atmosphere at the time and place of observation.

And it appears to me highly probable that the phenomenon which I have twice observed and reported, of Antares being projected upon the bright body of the moon for 2½ seconds after apparent contact with the limb and before the sudden disappearance of the star, may be due to the same cause—the moon's bright limb being so disturbed by irregular atmospheric refractions as to become blurred, confused, and apparently enlarged.

Therefore, to obtain the best results in all astronomical observations, we should make them at great and isolated elevations, where the atmospheric disturbance is a minimum. But if the high elevation be a plateau or only on the general level of the surrounding mountains we cannot expect so good results as on peaks or ridges rising high above them. Under such favorable conditions, and with equatorials of 8 inches, I believe we shall see Venus at the next transit long before the first and long after the last contact with sufficient definition to measure her distance from the sun, and that at contacts sharp limbs will be exhibited and closer times be observed.

Moreover, I suggest at the next transit of Mercury, in May, 1878, observations be made at great altitudes, as well as at low, with similar instruments, to obtain further results in this examination.

During the coming season, I hope to make test-observations upon the high summits of the Sierra Nevada, when occupying them for the geodetic purposes of the Coast Survey.

Yours, respectfully,

GEORGE DAVIDSON,
Assistant in the United States Coast Survey.

Mr. C. P. PATTERSON,
Superintendent United States Coast Survey, Washington, D. C.

APPENDIX No. 14.

REPORT ON THE TRANSIT OF VENUS EXPEDITION TO CHATHAM ISLAND, BY EDWIN SMITH, SUB-ASSISTANT IN THE UNITED STATES COAST SURVEY.

WASHINGTON, D. C., *June* 30, 1875.

SIR: I have the honor of submitting the following report of my duties under the Transit of Venus Commission, in conformity with your instructions, dated April 21, 1874:

I reported to the Honorable Secretary of the Navy, April 22, and received instructions to report to the President of the Transit of Venus Commission for further orders.

I reported officially to the President of the Commission at the Naval Observatory, Washington, D. C., April 25, but had already been at work there for several days. Mr. Albert H. Scott, of the Coast Survey, who had received instructions to report in the same manner as myself, but as assistant in my party, had done so, and was also at work at the observatory.

From this time to June 1, the time was occupied in testing the instruments, becoming familiar with the methods of observation, and in organizing the party.

During this time, I also observed for personal equations with the various observers at the observatory, for the longitude-work in the South, of the past winter.

On June 3, I received instructions from the Chief of the Bureau of Navigation to report to the Vice-Admiral at the navy-yard, New York, which I did, and received orders to report to Commander Ralph Chandler on board the Swatara, which I also did on the same date. My party also reported to me on board the Swatara, on June 3, in conformity with their instructions from the President of the Transit of Venus Commission.

When we left Washington, the organization of the party was as follows, viz: Edwin Smith, Subassistant in the United States Coast Survey, chief of the party; Albert H. Scott, United States Coast Survey, assistant astronomer; Louis Seebohm, chief photographer; Otto Buehler, first assistant photographer; W. H. Rau, second assistant photographer; and Sumner Tainter, intstrument-maker to the expedition, although attached to the party of Prof. William Harkness, U. S. N., was to remain at Chatham Island.

On June 6, the party was on board the United States sloop of war Swatara, under the command of Commander Ralph Chandler, U. S. N., lying off the Battery at New York. In New York, Mr. Louis Seebohm appeared to be in good health, but we had scarcely left the harbor when he began to suffer from sea-sickness, and continued to get worse. When we reached the equator, July 4, he was barely able to walk without assistance. By the advice of Captain Chandler and the surgeons of the Swatara, Drs. Kershner and Kidder, Mr. Seebohm was left at Bahia, Brazil, with money and instructions to return to the United States. Mr. Seebohm died at Bahia, of yellow fever, about ten days after the Swatara sailed. By instructions afterward received from the president of the commission, Mr. Buehler was made chief photographer, and Mr. Rau first assistant photographer.

At Hobart Town, Tasmania, agreeable to Captain Chandler's instructions from the honorable Secretary of the Navy, I took charge of the twenty chronometers for longitude, on board the Swatara. Their corrections on Hobart Town time had been determined and furnished me by Prof. William Harkness, U. S. N., chief of Hobart Town party. The Swatara sailed October 10, and frequent comparisons of the chronometers were made while at sea between Hobart Town and Chatham Island.

On the evening of October 19, the Swatara anchored in Whangaroa (Long Bay) Harbor, north side of Petre Bay, Chatham Island. The next day, the sites for the station and camp were selected, and work immediately begun. On the evening of October 21, camp was settled and the transit pier and house built ready to mount the instrument. The weather, however, did not admit of satisfactory observations till October 25, when the chronometers on board the Swatara were compared,

and turned over to Lieut. G. F. Wilkins, U. S. N., navigating officer of the Swatara. The Swatara sailed from Whangaroa at six o'clock on the morning of October 26.

Chatham Island is of small extent, being included in a circle of about thirty-five miles in diameter. The southern, western, and northern shores of the island are rocky, and rise abruptly about thirty or forty feet; the eastern shore is a long, low sand-beach, near which heavy seas continually break. Petre Bay is a large open bay on the western side of the island, and Whangaroa Harbor, a small bay on the north side of Petre Bay, is the only harbor on the island. It is small but perfectly safe for two or three vessels. (See sketch.) In the northern part of the island, several hills rise to the height of five and six hundred feet, the most prominent of which are Maunganui and Iwa Kawa, or Mount Dieffenbach. The latter is about five miles from Whangaroa, and had been selected for the station before leaving the United States, but it was impossible to get the instruments there and mounted in the limited time we had before the day of transit. The rocks are mostly basaltic, and pumice is found in considerable quantities, indicating the volcanic origin of the island. The soil in many places is very rich, and produces fine vegetables and grain. In other places it is clay covered with a peaty earth, which varies from a few inches to several feet in thickness. In the low parts this peat seems to be floating on water, and after a heavy rain it is impossible to cross it for several days. In some higher portions this peat has been burning for some thirty years. The grazing is very good in most parts of the island, and many sheep and cattle are raised. Few trees are found, and these only near the shores. The Chatham Island lily is a plant peculiar to the island. A great number of seeds and bulbs were brought to the United States, but were destroyed in transportation.

There are from two hundred and fifty to three hundred inhabitants on the island, about one-half of whom are Europeans. Of the remaining number about one-half are Moriories, the aborigines of the island, and the other half Moaries, from New Zealand. Several skulls of both these races were brought to the United States, and the most valuable sent to the Smithsonian Institution. The Europeans are mostly English and German, who performed various kind offices for us.

STATION.

The instruments were placed quite near the top of the hill, on the west side of Whangaroai Harbor, thus being protected from the strong westerly winds which prevail at Chatham Island, and still allowing a good view of the sun at the time of last contact, the sun then being only about 10 degrees above the horizon. They were nearly in the same meridian, the equatorial being 228 feet south of the transit-instrument. The transit and photographic instruments were about 65 and the equatorial about 85 feet above the level of the sea. (See accompanying sketch No. 25.)

FOUNDATIONS.

The soil in which the foundations were made is of clay. At the point where the photographic plate-holder pier was set the clay was so hard that the hole was made with considerable difficulty; but at the points where the photographic objective and transit piers were set the soil was so soft and wet that deep holes were made, drained, and foundations of stone and cement of over two feet n thickness made for the piers to rest upon. With the photographic objective, particularly, we had much difficulty. A hole more than five feet square about the pier was filled to the surface with stone and cement. The transit-pier was built of brick above the foundation, and capped with a single brownstone brought from America. Having no rain for two or three weeks, the soil all about became very hard.

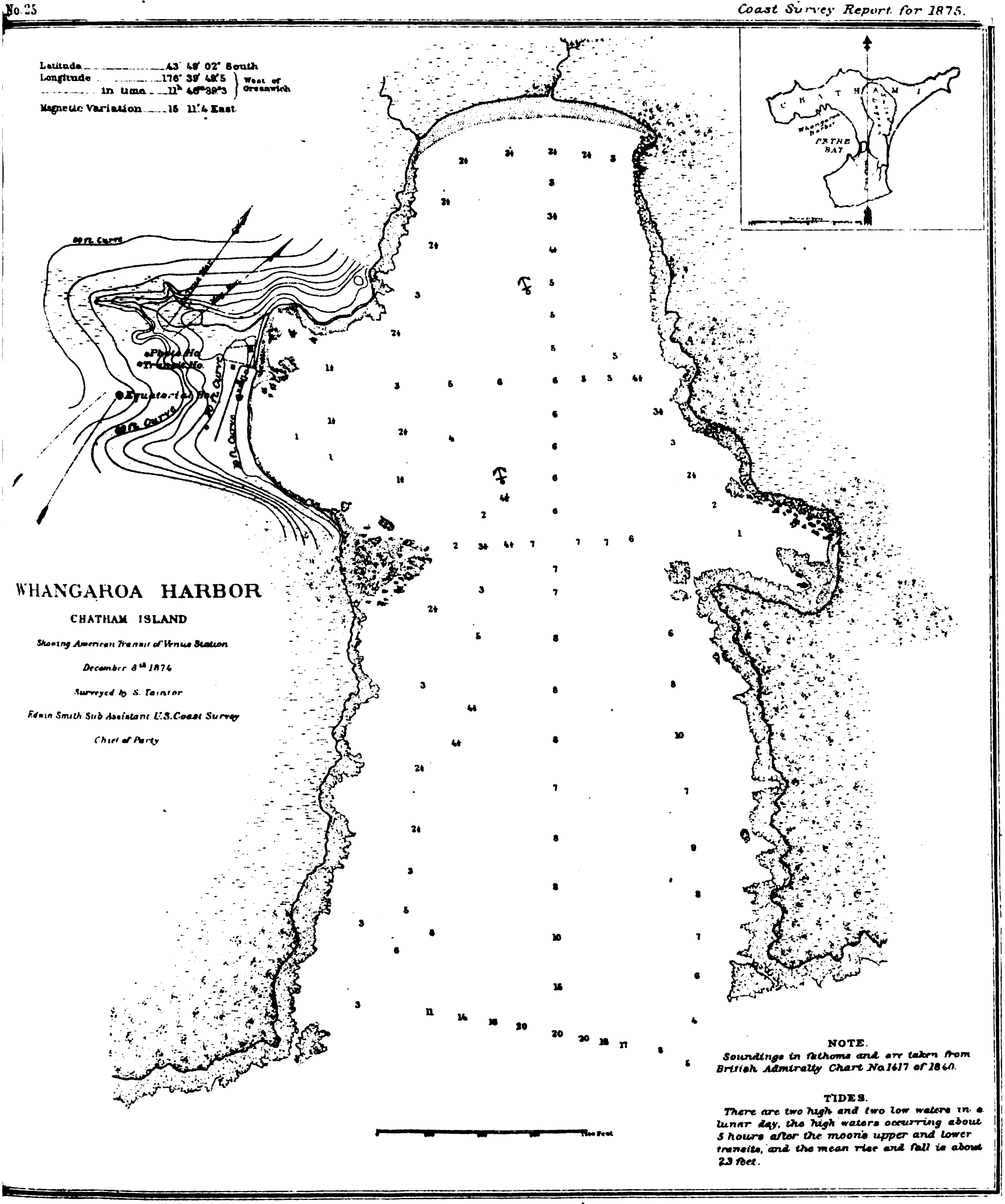
Owing to our small force and the difficulty of getting the material to the station, the work progressed slowly. Not a moment was lost, but still the equatorial was not ready for work till November 13, and regular practice in photography not begun till November 17.

INSTRUMENTS.

The following instruments were used at Chatham Island:
Stackpole transit No. 1506.
Clark & Son's equatorial telescope No. 861.

No. 25

Coast Survey Report for 1875.



A Hipp cylinder chronograph.

Chronometer Negus No. 1527, sidereal time and break circuit.

Chronometer Bond & Son No. 243, mean time.

Chronometer Bond & Son No. 387, sidereal time and break circuit (United States Coast Survey).

Zenith-telescope No. 6 (United States Coast Survey).

A clock was furnished, but not used.

Photographic apparatus with plate-holder No. 2.

Objective No. VII, reflector No. 1, heliostat No. 1.

Measuring-rod and an engineer's level.

Set of magnetic instruments, magnetometer No. 5, and dip-circle No. 105.

The records of each particular class of work contain all necessary information about the instruments used. The Hipp cylinder chronograph and the levels of the transit were not satisfactory.

OBSERVATIONS.

Previous to December 8, all the astronomical observations were made by myself; but after that date they were mostly made by Mr. Albert H. Scott.

All observations for latitude and errors of chronometers were made with the Stackpole transit No. 1506. For errors of chronometers, 172 observations were made on 59 stars on 21 nights. For latitude, 80 observations were made on 16 pairs of stars on 6 nights. The value of one revolution of the micrometer-screw was determined by four sets of observations on B. A. C. No. 4790, L. C., and ρ Octantis, L. C., on two nights. The value of one division of the level-scales and the inequality of the pivots had been determined at Washington.

The chronometers were compared twice each day, and, near December 8, three times. They were carefully protected from great changes of temperature, and their temperatures always recorded. After the transit, the value of one revolution of the screw of the double-image micrometer with highest power of the equatorial was determined from 38 observations of β Hydræ and 10 observations on γ Hydræ on three nights. The weather would admit of no occultations being observed. The United States Coast Survey zenith-telescope No. 6 was mounted, and an attempt made to get observations of equal altitudes on the moon and a star, but on one night only were we successful. This makes the longitude of Chatham Island depend entirely upon the chronometers on board the Swatara, which were compared twice at the island, on October 25, 1874, and January 3, 1875.

PHOTOGRAPHY.

The adjustments of the apparatus were frequently examined, and their errors determined. These observations show the instruments to have remained very steady. When practice was first begun, the image of the sun was very much blurred. It was soon discovered that both the reflector and objective were held too firmly in their cells, and by loosening the inner ring of the cells we obtained a much sharper image.

A contrivance was made to make twenty exposes on one plate of those small portions of the sun's limb where Venus should enter and leave the disk. It worked well, and we expected to get twenty such plates at both the beginning and ending of the transit. For some reason all the photographs obtained at Chatham are much thinner than is desirable. I endeavored to impress upon the photographers the necessity of the negatives being more dense, and for this reason, together with climate, some slight changes were made in the chemicals. A statement by Otto Buehler, chief photographer, to be found in the record, will explain.

DAY OF TRANSIT.

The duties of the members of the party on the day of the transit were as follows: Mr. Albert H. Scott, assistant astronomer, kept the record, and had general charge of the photographic operations; W. H. Rau, assistant photographer, prepared the plates and put them into the holder; Mr. Sumner Tainter, instrument-maker, made the exposures and read the level; Mr. Otto Buehler,

chief photographer, developed and finished the negatives, and was responsible for the good working of the chemicals; one of the men, named Turner, looked out for the heliostat and chronograph; assisted by Mr. W. Bouke, a German resident of the island, I observed with the equatorial.

On the 6th of December, fine observations for time were obtained and the azimuth of the photographic telescope carefully examined. These were the last observations previous to the transit. December 7 was a dark, dull, rainy day. The morning of December 8 was still cloudy. The instruments were carefully examined, however, and everything put in readiness for work. About noon, a few clear places were seen. At 1 p. m., one hour before first contact, every man was at his post in the photographic house. A moment later, on going to the equatorial, the spring governor of the driving clock was found broken. I immediately sent for Mr. Tainter, and by his skill and coolness the clock was taken off, spring repaired, and the instrument again in order at 1^h 40^m p. m., twenty minutes before first contact. Anxiously we now waited, hoping the contact might be seen through some of the thin clouds flying about. About sixteen minutes after first contact, a thinner cloud passed over the sun, and I obtained nine readings of the micrometer for measurements of cusps, though Venus and the sun could scarcely be seen, no shade-glass being used. At the photographic house, no reflection could be seen during this time. Had the reflector been silvered, perhaps we might have obtained contact-pictures. Nothing more was seen of the sun till fourteen minutes after second contact, when I obtained nineteen readings of micrometer to measure the shortest distance between the limbs of Venus and the sun. During this time a number of plates were exposed in the photographic house, but few are good. About twenty-eight minutes after second contact the sun came out bright, but not perfectly clear. Ten more micrometer-measures were made, and several very good photographs obtained. About forty minutes later the sun again appeared faintly, and eleven good measures of the diameter of Venus were obtained and more plates exposed. About one hour and sixteen minutes before third contact heavy clouds passed over the sun, and, shortly after, it began to rain. Rain ceased shortly before third contact, and when Venus was about half-way off the sun, I had a glimpse of her for about one second. Thirteen minutes after last contact the sun came out for a few minutes, after which it was not again seen from Chatham Island for several days. No more observations were possible till December 20. In the photographic operations twenty plates were exposed, thirteen of which show an image, but only eight are good. At no time was the sun perfectly clear of clouds, and in all the exposures the slide was moved by hand.

WORK AFTER THE TRANSIT.

A survey of the station and surroundings was made by myself, and afterward by Mr. S. Tainter, to include the entire harbor of Whangaroa. We had not the means of doing the hydrographic work necessary to make a complete chart. The tides, however, were observed. It is to be regretted that the hydrographic work was not done by the officers of the Swatara. This survey has been plotted and the map photolithographed by the United States Coast Survey, a copy of which accompanies this report.

A complete set of magnetic observations was made by Mr. Albert H. Scott; and after the transit the observations for intensity were repeated by myself.

The Swatara arrived on the morning of January 3, 1875. Observations for time were obtained, and the chronometers on board the Swatara compared for longitude that same night. By noon on January 5, all the Chatham Island party and instruments and equipage were on board the Swatara. The Swatara sailed a second time from Whangaroa Harbor on the morning of January 6.

The Swatara arrived at Port Chalmers, New Zealand, on January 10, and a copy of the Chatham Island records was immediately sent to Washington. The party remained together on board the Swatara till she arrived at Melbourne, February 19. Here, in conformity with instructions received through Captain Chandler, I advanced to each member of the party a sufficient sum of money to return to their homes by the mail-route, via San Francisco, with instructions to report by letter to the president of the Transit of Venus Commission. I left Melbourne on February 25, and arrived, via Europe, at New York, June 15, but a short time after the Swatara. Soon after my return, the original records of the Chatham party were sent to the commission.

On June 21, I reported in person to you at the Coast Survey Office, after which a few days were passed in settling my accounts and other work with the commission.

A complete copy of the Chatham Island records has been deposited at the Coast Survey Office, in conformity with your wishes.

COMPUTATIONS AND RESULTS.

Preliminary and partial computations of the observations for time, *latitude*, longitude, and *magnetics* were made while at Chatham Island.

In consequence of my going on duty in the Coast Survey very soon after my return to the United States, these unfinished computations were sent to the office, where the latitude and magnetic observations have been recomputed. These results are given in this report.

It is impossible to give the final result for longitude at present, as it depends upon observations at other stations and data which I have not at hand. From the preliminary computation of the first comparison of chronometers on board the Swatara at Chatham Island, the longitude of the station is 176° 39′ 50″ west.

LATITUDE-OBSERVATIONS.

The following observations for latitude were made with the Stackpole transit No. 1506. This instrument has a focal length of about thirty inches and a clear aperture of two and a half inches. A prism is placed in the axis and the eye-piece at one end of the axis similar to the Russian portable transits. The power used was sixty (very nearly). The micrometer has three parallel wires, called I, II, III. The distances between these wires in revolutions of the screw were accurately determined. Wire II was generally used. Whenever either of the other wires was used a note was made—a small correction being required to reduce it to wire II. The value of one division of the level-scales was determined with the Coast Survey level-trier in May, 1874, before leaving Washington. The value of one division of scale of level C used in these observations is 1″.418 This level was very unsatisfactory.

The value of one revolution of the micrometer-screw was determined by the following series of observations:

WHANGAROA, CHATHAM ISLAND, SOUTH PACIFIC OCEAN.

Value of micrometer of Stackpole transit No. 1506.

OBSERVER, EDWIN SMITH.

November 23, 1874.—Chronometer fast, $\Delta T = -26^s.5$.

No. 4790 B. A. C. (L. C.): $\alpha = 14^h\ 22^m\ 31^s.1$; $\delta = -87^\circ\ 37'\ 48''.6$.

No.	Micr. m.	Observed time by Bond 387.	No.	Micr. m.	Observed time by Bond 387.	No.	Micr. m.	Observed time by Bond 387.	No.	Micr. m.	Observed time by Bond 387.	No.	Micr. m.	Observed time by Bond 387.
	t	h. m. s.		t	h. m. s.		t	h. m. s.		t	h. m. s.		t	h. m. s.
1	39.	2 1 22.	14	32.5	2 13 27.	27	26.	2 25 33.	40	19.5	2 37 36.	53	......	....
2	38.5	2 19.5	15	32.	14 23.5	28	25.5	26 29.5	41	19.	38 31.5	54	......	....
3	38.	3 14.	16	31.5	15 20.	29	25.	27 25.5	42	18.5	39 26.5	55	......	....
4	37.5	4 10.	17	31.	16 17.5	30	24.5	28 21.	43	18.	40 22.	56	......	....
5	37.	5 6.5	18	30.5	17 13.5	31	24.	29 17.	44	17.5	41 19.	57	11.	2 53 22.5
6	36.5	6 2.5	19	30.	18 10.	32	23.5	30 12.5	45	17.	42 13.5	58	10.5	54 17.5
7	36.	6 58.	20	29.5	19 4.5	33	23.	31 8.	46	16.5	43 9.	59	10.	55 14.5
8	35.5	7 54.	21	29.	20 0.	34	22.5	32 2.	47	16.	44 4.5	60	9.5	56 11.
9	35.	8 50.	22	28.5	20 55.5	35	22.	32 57.	48	15.5	45 0.5	61	9.	57 7.
10	34.5	9 45.5	23	28.	21 51.	36	21.5	33 51.5	49	15.	45 56.5	62	8.5	58 2.
11	34.	10 40.5	24	27.5	22 46.	37	21.	34 47.	50	14.5	46 52.	63	8.	58 59.
12	33.5	11 37.5	25	27.	23 41.5	38	20.5	35 42.5	51	14.	47 49.	64	7.5	59 53.5
13	33.	12 31.5	26	26.5	24 37.	39	20.	36 39.5	52	13.5	48 45.5			

ρ Octantis (L. C.): $\alpha = 15^h\ 14^m\ 26^s.8$; $\delta = -84^\circ\ 02'\ 28''.3$.

No.	Micr. m.	Observed time by Bond 387.	No.	Micr. m.	Observed time by Bond 387.	No.	Micr. m.	Observed time by Bond 387.	No.	Micr. m.	Observed time by Bond 387.	No.	Micr. m.	Observed time by Bond 387.
1	40.	3 3 16.	12	34.5	3 7 20.	23	29.	3 11 23.	34	23.5	3 15 28.	45	18.	3 19 30.5
2	......	....	13	34.	7 42.	24	28.5	11 46.	35	23.	15 49.5	46	17.5	19 52.
3	39.	4 0.3	14	33.5	8 5.5	25	28.	12 8.5	36	22.5	16 12.5	47	17.	20 12.5
4	38.5	4 22.8	15	33.	8 28.	26	27.5	12 30.5	37	22.	16 34.5	48	16.5	20 35.5
5	38.	4 45.3	16	32.5	8 49.5	27	27.	12 52.	38	21.5	16 55.5	49	16.	20 58.5
6	37.5	5 7.	17	32.	9 11.	28	26.5	13 14.5	39	21.	17 18.	50	......	....
7	37.	5 28.5	18	31.5	9 34.	29	26.	13 36.	40	20.5	17 41.5	51	15.	21 42.
8	36.5	5 51.	19	31.	9 55.5	30	25.5	13 58.	41	20.	18 2.3			
9	36.	6 12.5	20	30.5	10 17.5	31	25.	14 21.	42	19.5	18 24.			
10	35.5	6 35.	21	......	....	32	24.5	14 43.5	43	19.	18 46.			
11	35.	6 58.	22	29.5	11 1.	33	24.	15 5.5	44	18.5	19 8.5			

WHANGAROA, CHATHAM ISLAND, SOUTH PACIFIC OCEAN.

Value of micrometer of Stackpole transit No. 1506.

OBSERVER, EDWIN SMITH.

November 27, 1874.—Chronometer fast, $\Delta T = -27^s.0$.

No.	Micr. m.	Observed time by Bond 387.	No.	Micr. m.	Observed time by Bond 387.	No.	Micr. m.	Observed time by Bond 387.	No.	Micr. m.	Observed time by Bond 387.	No.	Micr. m.	Observed time by Bond 387.
No. 4790 B. A. C. (L. C.): $\alpha = 14^h\ 28^m\ 32^s.6$; $\delta = -87°\ 37'\ 44''.8$.														
	t.	*h. m. s.*		*t.*	*h. m. s.*		*t.*	*h. m. s.*		*t.*	*h. m. s.*		*t.*	*h. m. s.*
1	30.	1 59 22.5	14	23.5	2 11 29.5	27	17.	2 23 33.5	40	......	....	53	4.	2 47 40.
2	29.5	2 0 17.5	15	23.	12 24.5	28	16.5	24 29.5	41	......	....	54	3.5	48 36.
3	29.	1 15.	16	22.5	13 20.5	29	16.	25 22.5	42	9.5	2 37 28.	55	3.	49 30.
4	28.5	2 10.5	17	22.	14 17.	30	15.5	26 19.5	43	9.	38 22.5	56	2.5	50 26.5
5	28.	3 7.	18	21.5	15 14.	31	15.	27 15.	44	8.5	39 18.5	57	2.	51 21.5
6	27.5	4 2.5	19	21.	16 9.5	32	......	....	45	8.	40 15.	58	1.5	52 27.5
7	27.	4 59.5	20	20.5	17 5.	33	......	....	46	7.5	41 10.5	59	1.	53 14.5
8	26.5	5 54.5	21	20.	18 1.	34	......	....	47	7.	42 5.5	60	0.5	54 11.
9	26.	6 50.	22	19.5	18 56.	35	13.	30 59.	48	6.5	43 1.	61	0.	55 5.
10	25.5	7 47.5	23	19.	19 50.	36	12.5	31 56.	49	6.	43 56.			
11	25.	8 43.5	24	18.5	20 47.5	37	......	....	50	5.5	44 51.5			
12	24.5	9 40.	25	18.	21 43.	38	......	....	51	5.	45 47.			
13	24.	10 35.	26	17.5	22 39.	39	......	....	52	4.5	46 44.			
ρ Octantis (L. C.): $\alpha = 15^h\ 14^m\ 27^s.3$; $\delta = -84°\ 02'\ 27''.1$.														
1	40.	3 2 20.4	13	34.	3 6 48.4	25	28.	3 11 12.0	37	22.	3 15 37.2	49	16.	3 20 5.0
2	39.5	2 43.6	14	33.5	7 10.0	26	27.5	11 34.6	38	21.5	16 0.1	50	15.5	20 25.3
3	39.	3 6.0	15	33.	7 32.6	27	27.	11 57.5	39	21.	16 23.0	51	15.	20 46.6
4	38.5	3 29.1	16	32.5	7 54.4	28	26.5	12 19.7	40	20.5	16 45.2	52	14.5	21 9.7
5	38.	3 50.5	17	32.	8 15.7	29	26.	12 41.6	41	20.	17 6.5	53	14.	21 30.7
6	37.5	4 12.7	18	31.5	8 38.4	30	25.5	13 3.9	42	19.5	17 29.9	54	13.5	21 55.5
7	37.	4 34.3	19	31.	9 0.8	31	25.	13 25.2	43	19.	17 51.8	55	13.	22 17.2
8	36.5	4 55.8	20	30.5	9 21.8	32	24.5	13 46.8	44	18.5	18 14.0	56	12.5	22 38.8
9	36.	5 18.7	21	30.	9 44.1	33	24.	14 10.3	45	18.	18 35.2	57	......	....
10	35.5	5 40.0	22	29.5	10 6.7	34	23.5	14 31.6	46	17.5	18 58.3	58	......	....
11	35.	6 2.5	23	29.	10 27.9	35	23.	14 55.4	47	17.	19 19.3	59	11.	23 46.2
12	34.5	6 25.6	24	28.5	10 50.5	36	22.5	15 16.7	48	16.5	19 43.3	60	10.5	24 8.5

The above observations were reduced by the method of least squares, giving the following results:

RESULT.

4790 B. A. C., November 23	68″.964 ± 0″.007	
4790 B. A. C., November 27	.970 ± 0 .006	68″.967 ± 0″.007
ρ Octantis, November 23	.913 ± 0 .017	
ρ Octantis, November 27	.935 ± 0 .012	68 .924 ± 0 .015
Result	± 0 .011	68 .946 ± 0 .011

The following are the observations and results for latitude; observer, Edwin Smith:

WHANGAROA, CHATHAM ISLAND, SOUTH PACIFIC OCEAN.

Latitude.—Stackpole transit No. 1506.

Date.	Star. No. B. A. C.	Star. N. S.	Micrometer-readings.	Level. N.	Level. S.	Meridian-distance.	Declination.	Corrections. Microm.	Corrections. Level.	Corrections. Refr.	Corrections. Wire merid.	Latitude.	Δ	Δ²	Remarks.
			R. D.			s.	° ′ ″	′ ″	′	′	″	° ′ ″	″	″	
1874. November 2	8178	S.	28 36.	31.4	18.1		− 45 11 38.03								
	8192	N.	28 53.5	11.9	25.2		− 42 26 48.03	− 0 0.17	+ 4.40	0.00		− 43 48 [68.80]	1.44	2.07	
3			28 49.5	29.7	16.4		38.19								
			28 39.5	16.4	29.9		48.19	+ 0 3.45	− 0.07	0.00		69.81	0.43	0.18	
5			28 79.5	25.7	12.0		38.51								
			28 73.5	12.0	25.7		48.51	+ 0 2.07	0.00	0.00		71.44	1.20	1.44	
6			28 74.5	25.4	11.4		38.67								
			28 61.5	12.0	26.1		48.67	+ 0 4.48	− 0.46	0.00		69.65	0.59	0.35	
8			27 22.	25.1	11.0		38.99								
			27 15.	9.9	24.0		48.99	+ 0 2.41	+ 0.78	0.00		70.80	0.56	0.31	
9			28 38.5	23.1	9.9		39.15								
			28 29.	10.0	23.1		49.15	+ 0 3.27	− 0.04	0.00		70.92	0.68	0.46	
												− 43 48 70.24			
November 2	8220	S.	13 03.	26.6	13.2		− 46 11 6.17								
	8258	N.	42 68.5	12.7	26.3		− 40 52 44.46	− 17 2.30	+ 0.28	− 0.29		− 43 48 57.63	1.01	1.02	
3			12 66.	23.5	9.9		6.34								Wire I observed at $23^h\ 30^m\ 49^s = +0^m.50^t$.
			42 35.5	8.8	22.2		44.63	− 17 3.68	+ 0.85	− 0.29	+ 1.71	56.90	1.74	3.03	
5			14 31.	25.9	12.1		6.68								Wire I $= +0^m.050^t$ } $= +0^m.041^t$.
			44 03.	12.0	25.9		44.97	− 17 4.55	+ 0.04	− 0.29	+ 1.41	59.22	0.58	0.34	Wire III $= -0\ .009$ }
6			12 71.5	26.0	11.9		6.85								Wire I.
			42 42.5	11.0	25.1		45.14	− 17 4.20	+ 0.64	− 0.29	+ 1.41	58.43	0.21	0.04	Wire III.
8			13 85.	24.6	10.5		7.20								Wire I.
			43 53.	10.5	24.7		45.49	− 17 3.17	− 0.04	− 0.29	+ 1.41	58.44	0.20	0.04	Wire III.
9			12 87.5	27.4	14.4		7.37								Wire I.
			42 71.	10.4	23.8		45.66	− 17 8.51	+ 2.69	− 0.29	+ 1.41	61.21	2.57	6.60	Wire III.
												− 43 48 58.64			
November 2	8332	N.	22 08.5	7.0	20.8		− 30 11 0.14								
	8369	S.	27 32.	19.5	5.6		− 57 39 8.65	+ 3 0.46	− 0.90	+ 0.05		− 43 52			
5			24 20.	12.0	25.7		0.59								
			29 97.5	25.1	11.4		9.28	+ 3 19.08	− 0.45	+ 0.06					
6			24 41.5	11.8	26.0		0.74								
			29 19.5	25.4	11.4		9.49	+ 3 19.25	− 0.35	+ 0.06					
8			24 81.5	7.8	22.3		1.04								
			29 59.5	22.2	7.8		9.90	+ 3 19.24	− 0.04	+ 0.06					
9			25 04.5	11.4	25.0		1.19								
			29 86.	24.4	10.8		10.11	+ 3 20.46	− 0.43	+ 0.06					

November 2	8352	N.	9 75.5	6.3	20.0	....	− 30 25 9.90								
	8377	S.	26 51.5	18.6	4.7	....	− 57 31 46.10	+ 9 37.77	− 1.06	+ 0.17	....	− 43 48 51.12	0.80	0.64	
5	....	...	11 86.5	12.0	25.7	....	10.35								
			28 71.5	23.0	9.0	....	46.73	+ 9 40.88	− 2.02	+ 0.17	....	− . 49.51	0.81	0.66	
6	....	..	12 03.	11.8	26.0	....	10.50								Wire I = $-0^{m}.050^{t}$.
			28 86.5	25.2	11.0	....	46.94	+ 9 40.36	− 0.57	+ 0.17	− 1.72	50.43	0.16	0.03	
8	....	..	12 55.5	7.8	22.3	....	10.80								Wire I.
			29 37.5	22.2	7.7	....	47.36	+ 9 39.84	− 0.07	+ 0.17	− 1.72	50.86	0.54	0.29	
9	....	...	12 62.	11.9	25.6	....	10.97								
			29 50.5	24.3	10.7	....	47.58	+ 9 42.08	− 0.89	+ 0.17	− 1.72	49.64	0.68	0.46	
												− 43 48 50.32			
November 2	31	S.	36 71.	27.0	13.1	....	− 55 46 9.73								
	43	N.	22 36.5	12.0	25.9	....	− 32 8 34.32	+ 8 14.52	+ 0.73	+ 0.14	....	− 43 48 66.58	0.30	0.09	
3	....	...	35 74.	26.1	12.1	....	09.95								Wire III = $+0^{m}.009^{t}$.
			21 44.	9.9	24.0	....	34.49	+ 8 12.97	+ 1.52	+ 0.14	+ 0.31	67.28	0.40	0.16	
5	....	..	36 69.	26.3	12.7	....	10.38								
			22 40.	10.5	24.3	....	34.82	+ 8 12.63	+ 1.49	+ 0.14	....	68.34	1.46	2.13	
6	....	...	35 81.5	21.9	7.7	....	10.60								Wire I = $-0^{m}.050^{t}$.
			21 35.5	7.9	21.8	....	34.99	+ 8 18.49	+ 0.04	+ 0.14	− 1.72	65.84	1.04	1.08	
8	....	...	36 34.	24.1	9.9	....	11.03								
			21 79.	13.9	28.2	....	35.32	+ 8 21.59	− 2.87	+ 0.14	− 1.72	66.03	0.85	0.72	Wire I.
9	....	...	37 22.5	26.1	12.9	....	11.24								
			22 80.5	12.0	25.2	....	35.4	+ 8 17.11	+ 0.64	+ 0.14	− 1.72	67.19	0.31	0.10	Wire I.
												− 43 48 66.88			
November 2	93	S.	20 81.	25.1	11.5	18	− 44 22 32.71								
	94	N.	34 88.	12.5	26.4	55	− 42 59 14.45	− 8 5.04	− 0.82	− 0.13	− 0.46	− 43 48 60.03	2.38	5.66	
3	....	...	21 06.5	26.0	12.0	28	32.91								
			35 32.	7.8	21.9	− 35	14.65	− 8 11.42	+ 2.94	− 0.13	− 0.58	62.97	0.56	0.31	Wire III = $-0^{m}.009^{t}$.
5	....	...	22 08.5	26.1	12.3	18	31.32								
			36 33.	10.8	24.7	30	15.06	− 8 11.08	+ 1.03	− 0.13	− 0.48	64.85	2.41	5.95	Wire III.
6	....	..	20 25.5	28.0	13.9	23	33.52								
			34 51.5	10.0	24.0	55	15.26	− 8 11.59	+ 2.80	− 0.13	− 0.79	64.10	1.69	2.86	Wire III.
8	....	...	21 03.	24.1	9.9	18	33.93								
			35 07.5	12.0	26.2	40	15.67	− 8 4.18	− 1.49	− 0.13	− 0.57	61.17	1.24	1.54	Wire III.
9	....	...	20 75.	24.7	11.4	18	34.14								
			34 86.	10.5	23.8	25	15.88	− 8 6.42	+ 0.64	− 0.13	− 0.44	61.36	1.05	1.10	Wire III.
												− 43 48 62.41			
November 2	119	S.	36 31.5	25.8	11.9	....	− 48 54 32.16								
	144	N.	38 44.	11.9	26.0	....	− 38 41 21.81	− 1 13.26	− 0.07	− 0.02	....	− 43 48 70.33	1.00	1.00	
5	....	...	40 25.	24.2	10.5	....	32.82								Wire III = $+0^{m}.009^{t}$.
			42 41.5	10.4	24.1	....	22.40	− 1 14.64	+ 0.07	− 0.02	....	72.20	0.87	0.76	Wire III = − 0.009.
8	....	...	41 62.	24.6	10.4	....	33.48								Wire III.
			43 72.5	10.5	24.5	....	22.98	− 1 12.57	0.00	− 0.02	....	70.82	0.51	0.26	Wire III.
9	....	...	40 75.	27.1	13.9	....	33.71								Wire III.
			42 89.5	13.2	26.5	....	23.18	− 1 13.95	+ 0.46	− 0.02	....	71.95	0.62	0.38	Wire III.
												− 43 48 71.33			

WHANGAROA, CHATHAM ISLAND, SOUTH PACIFIC OCEAN—Continued.

Latitude.—Stackpole transit No. 1506.

Date.	Star. No. B. A. C.	Star. N. S.	Micrometer-readings.	Level. N.	Level. S.	Meridian-distance.	Declination.	Corrections. Microm.	Corrections. Level.	Corrections. Refr.	Corrections. Wire merid.	Latitude.	Δ	Δ²	Remarks.
1874.			*R. D.*			*s.*	° ′ ″	′ ″	′	′	″	° ′ ″	″	″	
November 2	150	S.	25 11.	17.6	3.4	....	− 48 41 21.95								
	192	N.	14 29.5	6.0	20.1	....	− 39 9 3.87	+ 6 12.83	− 1.81	+ 0.10	......	− 43 48 61.79	0.99	0.98	
5	....	..	28 85.5	25.0	10.1	....	22.73								
			18 10.	10.0	24.0	....	4.48	+ 6 10.76	+ 0.39	+ 0.10	......	62.36	0.42	0.18	
6	....	...	29 79.	29.3	15.3	....	22.99								
			19 68.5	13.2	28.0	....	4.68	+ 6 9.04	+ 1.21	+ 0.10	......	63.49	0.71	0.50	
8	....	...	30 29.5	24.0	9.9	....	23.51								
			19 53.5	9.9	24.1	....	5.08	+ 6 10.93	− 0.04	+ 0.10	......	63.31	0.53	0.28	
9	....	...	29 48.	26.5	13.2	....	23.78								
			18 72.5	12.1	25.5	....	5.29	+ 6 10.76	+ 0.74	+ 0.10	......	62.94	0.16	0.03	
												− 43 48 62.78			
November 5	202	N.	20 18.5	10.0	24.0	....	− 39 6 28.04								
	212	S.	5 45.5	24.1	10.0	....	− 48 14 43.37	− 8 27.79	+ 0.04	− 0.14	+ 1.72	− 43 48 71.51	0.41	0.17	Wire I = + 0m 0.50s.
6	....	..	21 09.	13.1	28.1	....	47.51								
			6 34.5	27.9	13.7	....	43.61	− 8 28.31	+ 0.14	− 0.14	+ 1.72	72.15	1.05	1.10	Wire I.
8	....	..	21 53.5	9.9	24.1	....	47.92								
			6 77.5	26.2	11.9	....	44.06	− 8 28.82	+ 1.45	− 0.14	+ 1.72	71.78	0.68	0.46	Wire I.
9	....	..	20 72.	12.0	25.5	....	48.13								
			6 13.5	23.2	9.9	....	44.29	− 8 22.79	− 1.56	− 0.14	+ 1.72	68.98	2.12	4.49	Wire I.
												43 48 71.10			
November 2	236	S.	25 98.5	25.3	11.0	....	− 75 36 28.04								
	260	N.	30 27.	11.4	25.9	....	− 11 56 39.67	− 2 27.71	− 0.35	− 0.01	......	− 43 48 61.96	0.98	0.96	
5	....	..	25 42.	23.1	8.7	....	28.80								
			29 78.5	10.0	24.1	....	39.98	− 2 28.40	− 0.82	− 0.04	......	63.65	0.71	0.50	
6	....	...	25 70.5	25.0	10.8	....	29.05								
			29 96.5	12.0	26.1	....	40.08	− 2 26.85	− 0.82	− 0.04	......	62.27	0.67	0.45	
8	....	..	25 28.	25.7	11.3	....	29.56								
			29 61.	11.9	26.2	....	40.29	− 2 29.27	− 0.39	− 0.04	......	64.63	0.69	2.86	
9	....	..	25 78.5	23.2	9.9	....	29.83								
			30 05.	9.9	23.2	....	40.39	− 2 27.12	0.00	− 0.04	......	62.17	0.77	0.59	
												− 43 48 62.94			

November 5	272	N.	24 27.5	10.0	25.2	....	− 30 2 6.00								
	279	S.	24 59.	23.1	7.8	....	− 57 36 4.19	+ 0 10.86	− 1.52	0.00	....	− 43 48 55.76	1.26	1.59	
6	....	...	24 13.5	12.0	26.1	....	6.18								
			24 49.5	26.0	11.9	....	4.42	+ 0 12.41	− 0.07	0.00	....	52.96	1.54	2.37	
8	....	...	24 82.5	12.0	26.3	16	6.54								
			25 17.5	26.1	12.0	....	4.94	+ 0 12.07	− 0.07	0.00	− 0.03	53.77	0.73	0.53	
9	....	..	24 33.	13.7	27.1	....	6.72								
			24 63.	27.2	13.9	....	5.19	+ 0 10.34	+ 0.11	0.00	....	55.51.	1.01	1.02	
												− 43 48 54.50			
November 2	292	S.	29 91.	18.7	3.2	....	− 57 40 33.72								
	296	N.	17 13.5	10.0	25.3	60	− 30 11 53.12	+ 7 20.39	− 4.75	+ 0.13	− 0.43	− 43 48 58.08	0.87	0.76	
5	....	...	28 37.	23.1	7.8	....	34.50								
			15 64.	10.8	26.1	....	53.67	+ 7 18.84	− 2.13	+ 0.13	− 1.72	58.97	0.02	0.00	Wire I = − 0m. 050′.
6	....	..	28 25.	26.0	11.9	....	34.76								
			15 72.5	4.8	18.8	....	53.87	+ 7 11.77	+ 5.07	+ 0.12	− 1.72	59.08	0.13	0.02	Wire I.
8	....	...	28 95.	26.1	12.0	....	35.28								
			16 26.5	11.0	25.3	....	54.23	+ 7 17.29	+ 0.64	+ 0.13	− 1.72	58.42	0.53	0.28	Wire I.
9	....	...	28 41.5	27 2	13.9	....	35.53								
			15 76.	13.8	27.0	....	54.41	+ 7 16.25	+ 0.11	+ 0.13	− 1.72	60.20	1.25	1.56	Wire I.
												− 43 48 58.95			
November 2	340	S.	21 76.5	25.4	10.0	....	− 55 55 0.27								
	362	N.	34 97.	11.9	27.5	....	− 31 27 55.20	− 7 35.22	− 1.42	− 0.13	....	− 43 43 64.50	0.31	0.10	
5	....	...	21 63.5	26.9	11.5	....	1.05								
			34 91.	10.4	25.9	....	55.79	− 7 37.63	+ 0.74	− 0.13	....	65.44	1.25	1.56	
6	....	...	21 61.5	26.6	12.6	....	1.31								
			34 88.	12.0	26.0	....	55.98	− 7 37.28	+ 0.43	− 0.13	....	65.62	1.43	2.04	
8	....	...	21 55.	21.1	12.0	....	1.83								
			34 70.5	12.6	26.9	....	56.37	− 7 33.49	− 0.50	− 0.13	....	63.22	0.97	0.94	
9	....	...	21 49.	25.1	11.9	....	2.08								
			34 62.	12.0	25.2	....	56.56	− 7 32.63	− 0.07	− 0.13	....	62.15	2.04	4.16	
												− 43 48 64.19			
November 2	380	S.	32 76.	30.0	14.4	....	− 46 12 5.24								
	423	N.	23 78.	12.0	27.7	....	− 41 36 29.90	+ 5 9.57	+ 1.67	+ 0.08	....	43 48 66.25	1.26	1.59	
5	....	...	33 65.	27.6	12.0	....	5.96								
			24 58.	11.5	27.2	....	30.60	+ 5 12.67	+ 0.32	+ 0.08	....	65.21	0.22	0.05	
6	....	...	31 72.5	26.1	12.0	....	6.20								
			22 67.	10.8	25.0	....	30.84	+ 5 12.16	+ 0.82	+ 0.08	....	65.47	0.48	0.23	
8	....	..	32 84.	26.1	12.0	....	6.68								
			23 70.5	12.0	26.2	....	31.30	+ 5 14.91	− 0.04	+ 0.08	....	64.04	0.95	0.90	
9	....	...	33 30.	25.0	11.9	....	6.92								
			24 15.5	12.0	25.1	....	31.54	+ 5 15.26	− 0.07	+ 0.08	....	63.96	1.03	1.06	
												43 48 64.99			

WHANGAROA, CHATHAM ISLAND, SOUTH PACIFIC OCEAN—Continued.

Latitude.—Stackpole transit No. 1506.

Date.	Star. No. B. A. C.	Star. N. S.	Micrometer-readings.	Level. N.	Level. S.	Meridian-distance.	Declination.	Corrections. Microm.	Corrections. Level.	Corrections. Refr.	Corrections. Wire merid.	Latitude.	Δ	Δ²	Remarks.
1874.			*R. D.*			*s.*	° ′ ″	′ ″	′	′	″	° ′ ″	″	″	
November 2	461	S.	19 03.5	27.6	11.9	....	− 49 43 26.62								
	466	N.	40 05.5	12.0	27.6	....	− 37 30 33.00	− 12 4.57	− 0.04	− 0.20	....	− 43 48 64.62	0.74	0.55	
5	....	....	18 42.	25.7	10.0	....	27.40								
			39 48.	7.8	23.7	....	33.66	− 12 5.95	+ 1.49	− 0.20	− 0.57	65.76	0.40	0.16	Wire III observed at 1ʰ 27ᵐ 45ˢ.
6	....	....	18 84.5	28.0	14.0	....	27.65								
			39 85.	13.8	27.9	....	33.88	− 12 4.05	+ 0.11	− 0.20	− 0.31	65.21	0.15	0.02	Wire III = − 0ᵐ.009ᵗ.
8	....	....	18 94.	26.1	11.	....	28.18								
			39 88.5	14.7	26.9	....	34.34	− 12 1.98	+ 0.57	− 0.20	− 0.31	64.32	1.04	1.08	Wire III.
9	....	....	17 66.	25.4	12.4	....	28.45								
			38 74.	9.9	23.0	....	34.56	− 12 6.64	+ 1.74	− 0.20	− 0.31	66.91	1.55	2.40	Wire III.
												− 43 48 65.36			
November 2	489	N.	34 18.	3.1	18.9	....	− 30 32 56.17								
	521	S.	20 83.	18.8	3.1	....	− 56 49 50.77	− 7 40.22	− 0.04	− 0.13	....	− 43 48 63.86	0.04	0.00	
5	....	....	34 12.5	8.0	21.9	28	56.78								Wire III observed at 1ʰ 30ᵐ 30ˢ + 10ᵈ =
			20 73.5	27.9	12.0	....	51.60	− 7 41.60	+ 2.84	− 0.13	+ 0.22	62.86	0.96	0.92	+ 0ᵐ.009ᵗ.
6	....	....	33 39.	12.0	26.0	....	56.96								
			20 08.	26.0	12.0	....	51.87	− 7 38.84	0.00	− 0.13	....	63.39	0.43	0.18	
9	....	....	34 07.	12.0	25.0	....	57.58								
			20 72.	25.5	12.5	....	52.72	− 7 40.22	+ 0.35	− 0.13	....	65.15	1.33	1.77	
												− 43 48 63.82			

Mean places of stars observed for latitude of station Whangaroa, Chatham Island, South Pacific Ocean.

No. B. A. C.	B. A. C.	12 Y. C.	6 Y. C.	7 Y. C.	7 Y. C.	Rad. 2.	Armagh.	Wash.	Melbourne.	Cape.	Mean N. P. D. 1874. 0.
	° ′ ″										
8178	135 11 42. 90										42. 90
8192	132 26 53. 80							54. 50			54. 15
8220	136 11 12. 06										12. 06
8258	130 52 51. 98								52. 24		52. 11
8332	120 11 16. 25							11. 60			11. 60
8352	120 25 25. 83	20. 86	22. 02					21. 60			21. 49
8369	147 39 14. 18										14. 18
8377	147 31 52. 10										52. 10
31	145 46 16. 10										16. 10
43	122 08 45. 27							47. 68			46. 48
93	134 22 55. 94								42. 58		42. 58
94	132 59 19. 24								23. 92	25. 22	24. 57
119	138 54 41. 26										41. 26
144	128 41 33. 59										33. 59
150	138 41 31. 67										31. 67
192	129 09 11. 23							16. 15	16. 59		16. 37
202	129 06 59. 68							58. 96			59. 32
212	138 14 53. 18										53. 18
236	165 36 30. 42								34. 28		34. 28
260	101 56 57. 53				58. 44	60. 40	57. 57	57. 58			58. 50
272	120 02 21. 19	20. 49		21. 42				20. 00		20. 87	20. 80
279	147 36 14. 00										14. 00
292	147 40 44. 22										44. 22
296	120 11 46. 04					69. 82		68. 60			69. 20
340	145 55 27. 23								10. 04	12. 20	11. 12
362	121 28 06. 41								11. 10		11. 10
380	136 12 11. 01									18. 95	18. 95
423	131 36 44. 57										44. 57
461	139 43 45. 50								40. 45	41. 24	40. 70
466	127 30 48. 97										48. 97
489	120 33 13. 56										13. 56
521	146 49 55. 60								64. 53		64. 53

The proper motions given in the B. A. C. of many of the stars observed are derived from a comparison of their places in Lacaille's Catalogue (reduced to 1750) with their places in Brisbane's Catalogue (1825) and Taylor's Catalogue, and are little reliable. This appears from the wildness of several of the results for latitude where the places of the stars have only the B. A. C. authority. By omitting the proper motions altogether of such stars, results for latitude are obtained much more accordant with those obtained from pairs of stars, the places of which are found in the Melbourne and Washington Catalogues.

A correction has therefore been applied to several of the results for latitude based on the omission of proper motion.

Mean of epochs of Brisbane's and Taylor's Catalogues, 1831.

The same mean epochs when Rumker's Catalogue has been used.

No. B. A. C.	B. A. C. p. m. in N. P. D.	Catalogues used in B. A. C.	Number of years to 1875.	Amount of p. m. to be deducted.	Corr. to lat.
	″			″	″
8178	+ 0. 37	B. T. R.	44	+ 16. 28	+ 8. 14
8220	− 0. 26	B. T.	44	− 11. 44	− 5. 72
8377	− 0. 54	B. T. R.	44	− 23. 76	−11. 88
31	+ 0. 19	B.	50	+ 7. 50	+ 4. 75
119	+ 0. 36	B. T.	44	+ 15. 84	+ 7. 92
212	+ 0. 34	B. T.	44	+ 14. 96	+ 7. 48
279	− 0. 44	B. T. R.	44	− 19. 36	− 9. 68
292	− 0. 19	B. T. R.	44	− 8. 36	− 4. 18
466	+ 0. 14	B. T.	44	+ 6. 16	+ 3. 08

Results for latitude of transit of Venus.

Station WHANGAROA, Chatham Island.

Pair. B. A. C.		Latitude.	Corr. to lat.	Corrected lat.	Δ′	Δ′ ²
		° ′ ″	″	° ′ ″		
8178	8192	−43 49 10.24	+ 8.14	−43 49 02.10	1.14	1.30
8220	8258	48 58.64	− 5.72	04.36	1.12	1.25
8352	8377	48 50.32	−11.88	02.20	1.04	1.08
31	43	49 06.88	+ 4.75	02.13	1.11	1.23
93	94	49 02.41	....	02.41	0.83	0.69
119	144	49 11.33	+ 7.92	03.41	0.17	0.03
150	192	49 02.78	....	02.78	0.46	0.21
202	212	49 11.10	+ 7.48	03.62	0.38	0.14
236	260	49 02.94	....	02.94	0.30	0.09
272	279	48 54.50	− 9.68	04.18	0.94	0.88
292	296	48 58.95	− 4.18	03.13	0.11	0.01
310	362	49 04.19	....	04.19	0.95	0.90
380	423	49 04.99	....	04.99	1.75	3.06
461	466	49 05.36	+ 3.08	02.28	0.96	0.92
489	521	49 03.82	....	03.82	0.58	0.34
Mean	....			−43 49 03.24		

Latitude .... 43° 49′ 03″.24 ± 0″.16

Number of pairs .... = 15

Number of observations .... = 75

Average number of observations upon a pair .... = 5

$$\Sigma \triangle^2 = 83.45$$

$$\Sigma \triangle'^2 = 12.13$$

$e_0 = \pm 0''.80$ probable error of a single observation.

$e_{\frac{**}{2}} = \pm 0\ .51$ probable error of declination.

$\varepsilon = \pm 0\ .16$ probable error of final result.

The final result for latitude is satisfactory, and far within the limit of accuracy required. The probable error of a single observation (± 0″.8) is about double that I usually get with the Coast Survey meridian-telescopes, made by Würdemann, which have a focal length of only 26 inches and a clear aperture of only 1¾ inches, with a power of about 60. The large probable error with the Stackpole transit was probably due to the bad level.

MAGNETIC OBSERVATIONS.

The following determinations of the magnetic elements were made at a point SW. by S. from the camp, about 200 feet from the shore of Whangaroa Bay and just at the foot of a low hill covered with a dense growth of coarse grass and heath. In all this part (western) of Chatham Island, the rocks are basalts and micaceous clay-slates; this latter being largely veined with quartz. There are no rocks in the immediate vicinity of the magnetic station, the nearest being the micaceous slates which crop out along the shores of the bay.

Latitude of magnetic station .... 43° 49′ 03″

Longitude of magnetic station .... $12^h\ 13^m\ 21^s$ east of Greenwich.

The instruments used at Chatham Island have already been mentioned. They are very similar to the instruments that have been used by the Coast Survey for many years. They were new, and had never been tested before being used at Chatham Island.

The magnets had been badly magnetized, and we had no means of properly correcting this fault.

Magnetometer No. 5 was furnished with two collimator-magnets, marked T. V. No. 9 and T. V. No. 10. They were both about three-quarters of an inch in diameter, No. 9 being one and nine-tenths inches and No. 10 one and four-tenths inches long. Both magnets have scales divided

from 0 to 160. During the observations for declination the value of one division of the scale of each magnet was determined to be as follows: For No. 9, 1 division = 2'.374; for No. 10, 1 division = 2'.728. At the same time, the reading of the axis of magnet No. 9 was found to be 114.63 divisions.

Observations to determine the temperature co-efficient (q) of magnet No. 9 were made, but the changes of temperature were too rapid to give reliable results; q has been assumed to be 0.0003.

Inertia-ring No. 5 belonging to this instrument was weighed and measured at the Coast Survey Office April, 1874, but the temperature was not given.

Weight of ring No. 5	1,351.05 grains.
Outer diameter	2.594 inches.
Inner diameter	2.007 inches.
Thickness	0.298 inches.

The methods of observation and reduction are those now used by the Coast Survey, and are given in a paper by Charles A. Schott, assistant in the Coast Survey, in the report of 1872.

Magnetic declination.

OBSERVATIONS ON SUN FOR AZIMUTH.

Observer, A. H. SCOTT. Theodolite attached to magnetometer No. 5.

Date.	Chron. time of obser.	Chron. corr'n.	Mean time of obser.	Azimuth of sun from north.	Circle readings on sun.*	Circle reading of N. meridian.
1874.	h. m. s.	m. s.	h. m. s.	° ' "	° ' "	° '
December 2, P. M.	4 54 03.7	+ 1 31.3	4 55 35.0	97 34 39	51 21 27	148 56.06
December 3, P. M.	4 44 51.8	+ 1 31.1	4 46 24.9	96 08 49	52 47 40	56.29
December 3, P. M.	4 53 41.8	+ 1 31.1	4 55 12.9	97 34 48	51 22 25	57.13
December 3, P. M.	5 03 38.2	+ 1 31.1	5 05 09.3	99 11 10	49 46 08	148 57.18
Mean						148 56.8

* Mean of six observations.

DECLINATION.

Observer, A. H. SCOTT. Magnet No. 9 suspended. Reading of axis, 114.63 div.

Date.	Mean scale-reading of E. and W. elongation	Reduction to axis.		Reading of circle.	Circle reading of mag. meridian.	Magnetic declination east of north.
		Divisions.	Arc.			
1874.	d.	d.	° '	° '	° '	° '
December 1	83.60	31.03	1 13.6	165 17.0	164 03.4	15 06.6
December 2	85.37	29.26	1 09.4	165 17.0	164 07.6	15 10.8
December 3	85.77	28.86	1 08.5	165 17.0	164 08.5	15 11.7
Mean						15 09.7

Magnetic dip.

The dip was observed at three stations (see sketch), A, B, C, the latter being the true magnetic station.

November 23, 1874. Observer, A. H. SCOTT.

Station.	Time.	Polarity.	Needle A 1. *Mean dip.	Needle A 1. Mean of polarity N. and S.	Needle A 2. *Mean dip.	Needle A 2. Mean of polarity N. and S.
	A. M.		° ′	° ′	° ′	° ′
A	10h 24m	N	66 24.0	....	66 17.8	....
	10 55	S	65 53.7	66 08.9	66 11.6	66 14.7
	P. M.					
	2h 56m	S	65 47.2	....	66 02.7	....
	3 31	N	66 18.5	66 02.8	66 15.9	66 09.3
	A. M.					
B	11h 45m	S	65 32.8	....	66 08.4	....
	P. M.					
	0h 20m	N	65 50.6	65 41.7	66 04.7	66 06.6
	4 14	N	65 46.6	....	66 09.1	....
	4 41	S	65 32.5	65 39.5	66 01.9	66 05.5
C	0 54	N	66 05.9	....	65 55.0	....
	1 23	S	65 37.2	65 51.6	66 05.2	66 00.
	5 12	S	65 31.2	....	66 10.9	....
	5 43	N	66 59.6	65 45.4	65 55.3	66 03.1
	Means..................			65 51.7	....	66 06.5

* Mean of sixteen readings with circle west and east, face west and east.
Mean of the two needles, —65° 59′.1. (The minus sign indicates the south end dipping.)

Horizontal intensity.

DEFLECTIONS.

Observer, A. H. SCOTT. Magnet No. 9 deflecting in mag. prime vertical and magnet No. 10 suspended.

DECEMBER 7, 1874.

Time of observation.	Temp. t. Fah.	Radius. r.	Angle of deflection. u.	$\log\left(1+\frac{h}{f}\right)$	u in arc.	$\log \frac{m}{H}$*
A. M	°	*Ft.*	*d.*†		° ′	
11h 24m.2	68.27	1.5	29.166	0.00352	1 28.210	8.59528
11 38 .5	68.00	2.0	12.375	0.00352	0 34.034	8.59772
P. M.						
0 17 .5	65.62	1.5	29.155	0.00352	1 20.180	8.59510
0 30 .7	64.00	2.0	12.360	0.00352	0 3 .990	3.59716

$t = 66°.5$ Fah. $\log \frac{m}{H} = 8.5963$ '.

Observer, EDWIN SMITH. Magnets as above.

DECEMBER 31, 1874.

Time of observation.	Temp. t. Fah.	Radius. r.	Angle of deflection. u.	$\log\left(1+\frac{h}{f}\right)$	u in arc.	$\log \frac{m}{H}$*
A. M.						
9 52 .6	76.12	1.5	28.810	0.00384	1 19.290	8.59027
10 10 .0	76.70	2.2	9.195	0.00384	0 25.310	8.59325
10 25 .9	77.50	1.5	28.875	0.00384	1 19.480	8.59130
10 41 .9	77.15	2.2	9.225	0.00384	0 25.390	8.59463

$t = 76°.87$ $\log \frac{m}{H} = 8.59236.$

$$* \frac{m}{H} = \frac{1}{2} r^3 \tan . u \left(1 - \frac{P}{r^2} \quad . \quad . \quad . \right)$$

† Mean of four results.

Horizontal intensity—Continued.

OSCILLATIONS.

Observer, A. H. SCOTT. Magnet No. 9 suspended.

$$T^2 = T'^2 \left(1 + \frac{h}{f}\right) (1 - (t' - t)\, q)$$

$$K = K_1 \left(\frac{T^2}{T_1^2 - T^2}\right).\quad K \text{ is moment of inertia of ring,}$$

$$m\, H = \frac{\pi^2 K}{T^2}$$

From ten results for time of thirty oscillations.

Date.	Time of one oscillation corr'd for rate. T'.	Temp. t'.	$\log\left(1+\frac{h}{f}\right)$	log T² and log T,².	K.	m.	Horizontal intensity. H.
1874.	s.	°					
December 6	10.9208	.1.15	0.00219	2.07808	....	0.2056	5.209
December 7	10.9053	70.10	0.00363	2.07843	1.11322	0.2055	5.207
December 7	(15.2737)*	68.90	0.00557	2.37317†	....	....	....
December 7	10.8993	69.10	0.00365	2.07808	1.11383	0.2056	5.209
December 7	(15.2503)*	66.50	0.00567	2.37223†	....	....	....
Means					1.11353	0.2056	5.2083
Observer, EDWIN SMITH. Magnet No. 9 suspended. From six results for time of thirty oscillations.							
December 29	10.9012	72.60	0.00425	2.07975	....	0.2041	5.217
December 30	10.8971	72.55	0.00407	2.07925	1.11055	0.2042	5.220
December 30	(15.3054)*	75.00	0.00641	2.37637†	....	....	....
December 30	10.9221	75.35	0.00419	2.08101	1.11304	0.2038	5.209
December 30	(15.2965)*	75.00	0.00623	2.37567†	....	....	....
December 30	10.9299	75.15	0.00405	2.08151	1.11426	0.2037	5.206
Means					1.11264	0.2040	5.2130

* Inertia ring used. † log T,².

Magnetic results.

Horizontal intensity (Scott) 5.2083
(Smith) 5.2130

Mean 5.2107

Final result for dip .... 65° 59'.1

Total intensity 12.803

Vertical intensity .... — 11.695

The above are in absolute measure, and expressed in English units.

Magnetic declination .... — 15° 09'.7

In the report upon these computations by Charles A. Schott, in charge of computing division of the Coast Survey, to the assistant in charge of office, I find the following: "Comparing the above results with those obtained by Capt. Sir James Ross near the island in the Erebus and Terror expedition, between May, 1841, and August, 1842 (Lieut. Gen. Sir Edward Sabine's Contributions to Terrestrial Magnetism No. XI, Trans. Royal Society, June, 1868), we may deduce the following apparent annual change during the interval of thirty-three years:

"Declination, 1841–'42, latitude = — 43° 37', longitude = 183° 05' east of Greenwich, — 14° 46' Annual increase, — 0'.7.

"Dip, 1841–'42, latitude = $\left\{\begin{matrix} -43^\circ\ 32' \\ -43^\circ\ 52' \end{matrix}\right\}$, longitude = $\left\{\begin{matrix} 183^\circ\ 03' \\ 183^\circ\ 05' \end{matrix}\right\}$ east of Greenwich — 64° 48 and — 65° 16'. Mean, — 65° 02'. Annual increase, 1''.7.

"Intensity, 1841–'42, positions nearly as above. Corrected total intensity, 12.55 and 12.56. Annual increase, .0075.

"Respecting the annual variation of these magnetic elements, we possess very little information; but by comparing the values of 1841–'42 with the charts for 1870 appended to Capt. F. I. Evans' Manual for the Deviation of the Compass in Iron Ships, London, 1870, we find that the east declination has been increased, as well as the south dip and the total intensity; all of which is in conformity with our results."

Before closing this report, I wish to extend my thanks to the commission for the completeness with which everything was provided for our health and comfort. While on the island, we lived in tents, and no serious illness was known to any of the party. On the Swatara, the party was treated with kindness and courtesy by the captain and officers.

Very respectfully, yours,

EDWIN SMITH,
Subassistant in the United States Coast Survey.

Capt. C. P. PATTERSON,
Superintendent United States Coast Survey, Washington, D. C.

APPENDIX No. 15.

DESCRIPTION OF AN APPARATUS FOR RECORDING THE MEAN OF THE TIMES OF A SET OF OBSERVATIONS, BY C. S. PEIRCE, ASSISTANT IN THE UNITED STATES COAST SURVEY.

The object of the contrivance is to enable an observer, after he has touched a key at each one of several observations, which succeed at a constant interval of a few seconds, immediately to read off on a dial the mean of the times of the observations to hundredths or thousandths of a second, thus avoiding the delay, labor, and error involved in reading chronograph-sheets.

Suppose the number of observations in a set is n. Then, if t_i is the time of the ith observation the mean time is—

$$\frac{1}{n}\Sigma_i t_i$$

Let S_i be double the number of whole seconds in t_i, and let s_i be the fraction of a second. Then—

$$\frac{1}{n}\Sigma_i t_i = \frac{1}{n}\Sigma_i S_i + \Sigma_i \frac{s_i}{n}$$

The problem thus divides itself into two, to determine each term of the second member of this equation. This division of the problem constitutes the first essential character of the method here to be described.

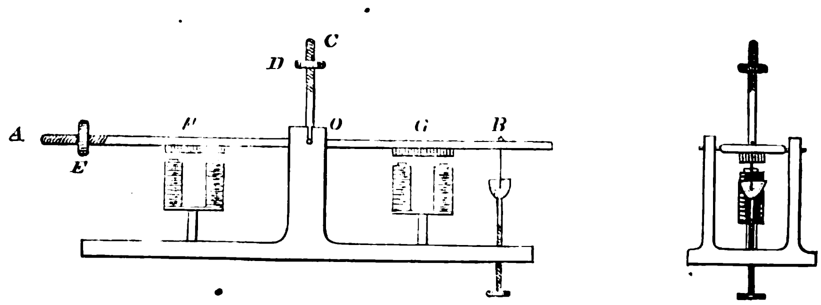
If the observations occur at irregular and unknown intervals, the observer may separately note S_i for each observation, without any particular apparatus, and so calculate the first term. But if the observations occur at intervals approximately known, the first term can be determined with less trouble. Suppose, for instance, that the observations, like transits of stars, are known to occur at intervals nearly symmetrical about the middle one. Then, if there exists any easy means of determining the time of this one accurately to the one nth part of a second, this will be equal to the first term, provided the observations follow one another with sufficient regularity. But if n be too great for this, or if it be an even number, the observer may note, by any simple means, the times of the first and last observations. These times need then only be noted to two $n$ths of a second, and so for any larger numbers. A transit-observer may conveniently use seven wires, and note the times over the second and sixth wires to a quarter of a second. When n is greater, a marking-watch may be conveniently used. In using this instrument, the observer need not seek to distinguish the different observations of a set, as their order does not affect the mean value.

I have now to describe the means by which I would determine the value of the second term—

$$\Sigma_i \frac{s_i}{n}$$

Supposing that we have the means of registering the sum of the fractions s_i. Then to register, nstead, their mean, we may use one of the following methods: First, we may regulate the registering apparatus by a "regulateur Villarceau." This may be made to run at any desired rate within certain limits with great accuracy; and it should be made to run at one nth of the rate required for the registry of the sum of s_i. Second, we may have a frictional connection between two solids of revolution. Third, we may perform the required division by the graduation of the dial by changing from one dial-face to another. But the simple division of Σs by n is so very easily performed that it would hardly be worth while to make the necessary adjustment of the apparatus to put any of these methods into practice. I will, therefore, proceed at once to describe a contrivance for registering Σs.

We require for this purpose three special pieces of apparatus besides the usual break-circuit chronometer. The first is a Hipp's chronoscope. Only, it would generally be better to have an instrument on a similar plan but registering hundredths instead of thousandths of a second, and running for five minutes at least.* The essence of the instrument is a train of clock-work, running rapidly and regularly, and a dial with a hand connected with wheels, which are thrown into gear with the train when a certain galvanic circuit is made (or broken), and which are thrown out and stopped when the circuit is broken (or made). The second instrument needed is an observing-key, made something like a piano-forte key, with a metallic hammer, for making a very short galvanic connection. The third instrument is a peculiar relay, constructed as follows:



O is a fixed axis, about which turns a lever, A B, which is provided with a vertical arm, O C. Upon this arm, there is a movable counterpoise, D, for raising or lowering the mass. On the arm A there is another weight, E, to adjust the balance of the lever. At the end B there is a platinum point, which dips into a mercury-cup, the height of which is adjustable by a screw. At F and G are armatures, and below each a small electro-magnet. The lever will turn to a limited extent, and is so balanced that it will remain with either end down when it is thrown from one position to the other.

Four batteries are now to be arranged in three connections, as follows:*

1st, Copper; mercury-cup; chronoscope; zinc.

2d, Copper; electro-magnet G; key; zinc.

3d, $\left\{\begin{array}{l}\text{Copper, first battery;}\\ \text{Zinc, second battery;}\end{array}\right\}$ electro-magnet F; $\left\{\begin{array}{l}\text{chronometer; zinc, first battery.}\\ \text{copper, second battery.}\end{array}\right.$

Before the observations begin, the A end of the relay will be down, and there will be no current through the chronoscope, and the hands will be still. When the key is touched, the electro-magnet G is made effective, the B end of the lever goes down, the first current is made, and the chronoscope-hand moves. This continues until the next chronometer-second, when the circuit through the first battery of the third connection is broken so that the second battery is no longer neutralized as it should have been at first; the electro-magnet F is made, the B end of the relay goes down, the circuit through the mercury-cup is broken, and the chronoscope stops. By reading the dial of the chronoscope before and after the set of observations, we have the quantity—

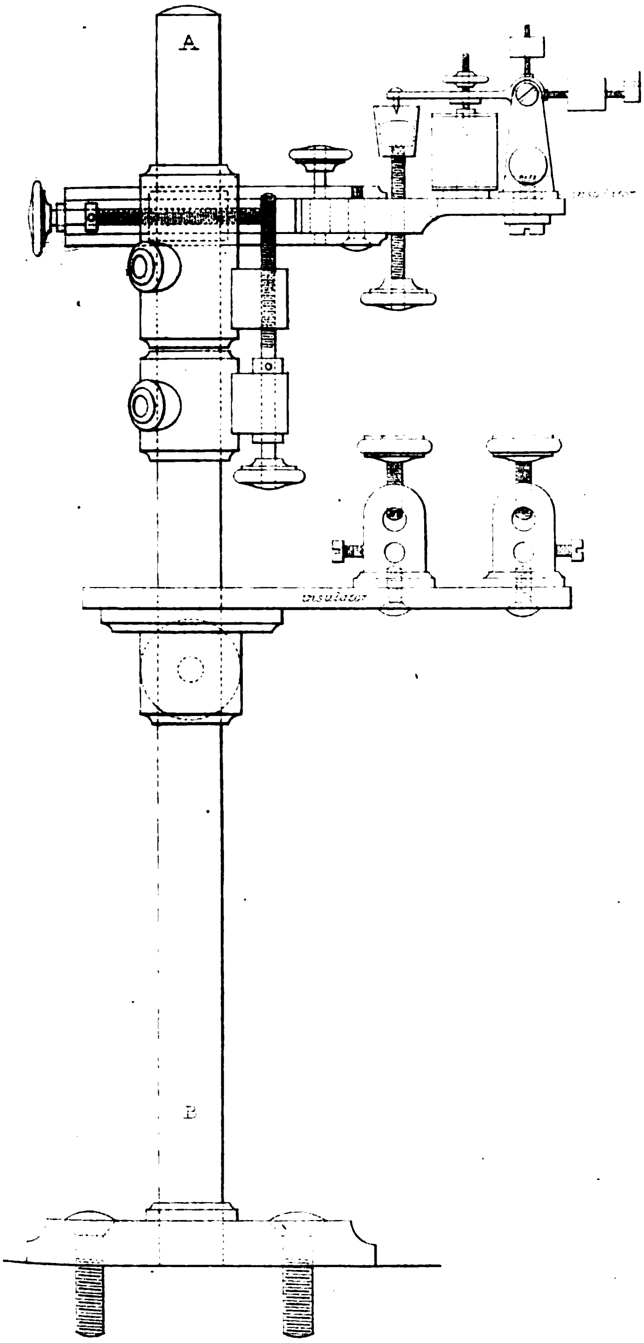
$$n - \Sigma_i s_i$$

The interference of the observer's signal with the chronometer-second may produce either of two effects: it will either add one second to the recorded sum or will cause the omission of one observation. Either effect is easily detected in the result.

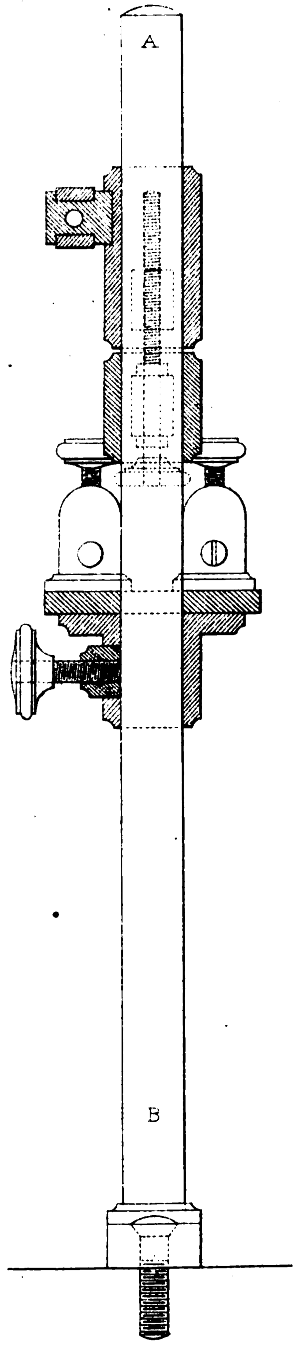
I have had constructed a relay of the sort described above, only replacing the magnet F by an agate which can be struck by a pendulum for determining gravity.

In the Coast Survey Report for 1870, page 212, I have shown the existence of a correction to the times as given by Hipp's chronoscope, owing to the inertia and friction of the wheels connected with the hands, in consequence of which, as soon as they are geared in, the movement begins to be retarded and they move slower and slower during three-fourths of a second. As the

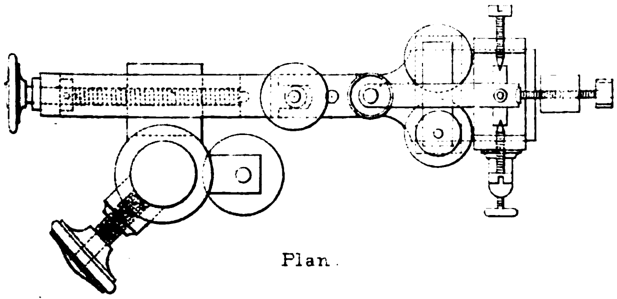
* A still better arrangement would be to have a make-circuit chronometer.



Elevation.



Section A B.



Plan.

APPARATUS FOR RECORDING A

MEAN OF OBSERVED TIMES

devised by

C. S. PEIRCE, Assistant

U.S. COAST SURVEY

1875

instrument is regulated by a vibrating reed striking the teeth of a revolving wheel, we should expect the retardation to vary as the velocity, so that—

$$D_t^2 s = a - v D_t s$$

the integral of which is of the form—

$$s = A t + B (1 - 6^{-ct})$$

Here t denotes the time and s the reading of the chronoscope. The existence of this correction is also shown by attentively listening to the note of the reed, which is distinctly heard to be lowered when the hands are geared in. It must be confessed, however, that the measured times of known intervals are not accounted for by this correction; for example, at Berlin, in 1876, May 10 and 11, I experimented on the fall of a ball. The length of the seconds' pendulum at Berlin, according to Bessel, as stated by Bruhns, is $0^m.9942318$. This is for the level of the sea; for my point it is .994223. The reciprocal of this, or 1.00581, is the square of the time in mean seconds of the vibration of a metre-pendulum. The square root of this, or 1.00290, is the time itself. Multiplying by $\frac{366}{365}$ we get 1.00565, the time in sidereal seconds. The square of this, or 1.01133, is then to be multiplied by $\frac{1}{\partial^2}$ or, .101321 to get the velocity square in sidereal seconds after a fall of one metre. This is .102469. If, therefore, the true squares by the chronoscope of a fall through 5 centimetres be divided by .0102469, we get the square time by the chronoscope divided by the sidereal seconds. Now, then, A being nearly 40.1 millimetres and B being nearly 19.6 millimetres, I found—

Heights.	Chronoscope.	(Chron.)²	Δ	$\frac{\Delta}{.01025}$	$\frac{\text{Chron.}}{\text{Sid. sec.}}$
A.	.0919	.00845	.01090	1.064	1.032
A + 5 cen.	.1391	.01935	.01037	1.012	1.006
A + 10 cen.	.1724	.02972	.01076	1.050	1.025
A + 15 cen.	.2012	.04048	.01010	.986	.993
A + 20 cen.	.2249	.05058	.01048	1.023	1.011
A + 25 cen.	.2471	.06106	.01028	1.003	1.001
A + 30 cen.	.2671	.07134	.01097	1.071	1.035
A + 35 cen.	.2869	.08231	.00986	.962	.981
A + 40 cen.	.3036	.09217	.01094	1.068	1.034
A + 45 cen.	.3211	.10311	.01046	1.021	1.010
A + 50 cen.	.3370	.11357	....	....	....
B.	.0637	.00406	.00101	.986	.993
B + 5 m.	.0712	.00507	.00108	1.054	1.027
B + 10 m.	.0784	.00615	.00104	1.015	1.007
B + 15 m.	.0848	.00719	....	....	....

I also measured some clock-intervals, with the following results:

Interval in sid. sec.	Chronoscope.	Δ	$\frac{\text{Chron.}}{\text{sid. sec.}}$
1	.996	.996	0.996
2	1.993	.997	0.997
10	9.956	7.963	0.9954
50	49.745	39.789	0.9947

If we take the times of falling through A and B, we have—

Height.	(Chron.)²	$\frac{(\text{Chron.}^2)}{\text{Height.}}$	$\frac{(\text{Chron.})^2}{205\ \text{height.}}$	$\frac{\text{Chron.}}{\text{sid. sec.}}$
.0401	.00845	.211	1.03	1.02
.0196	.00406	.207	1.01	1.01

If we compare the time of falling A + 50 cen. with the record of 1 second, we have $54.01 \times .00205 = .1083 = (.3291)^2$. Hence the difference of time is 0.6709 sidereal second. The difference of the chronoscope results is 0.659, and the ratio is only .982.

That there really is a retardation is certain both *à priori* and from the sound; and it is shown by the rates from the clock-seconds. But this can hardly account for the discrepancy between the measures with the clock and fall-apparatus, for the last given rate connecting the two is too small. I am inclined to think that there may be a correction of the fall-experiments, proportional to the momentum at impact, and, therefore, to the time. Experiments should be made with pendulums of different lengths. The relay above described, with the addition of a circuit-reverser, will render such experiments easy.

In regard to the accuracy of Hipp's chronoscope, I may mention that the chronoscope-times given above for the falls are the means of ten observations each. It may, then, be calculated from the agreement of the resulting ratios in the last column that the probable error of a single observation but slightly exceeds one thousandth of a second. In using the instrument for the automatic record of pendulum-transits, then, it will be quite sufficient to have ten observations in a set. This will give the intervals accurately to a thousandth of a second, or as accurately as the method of coincidences.

Let us now briefly consider the effect of the resistance of the lever shown in the plate upon the motion of the pendulum. Owing to the elasticity of the material, we may consider the impact to be instantaneous and to produce a reduction of the velocity of the pendulum in a fixed ratio. Let t be the variable time which is occupied by the pendulum in swinging from the vertical position to one having an angle, φ, from the vertical; let v be the angular velocity at that instant; T, the period of oscillation; Φ, the amplitude of oscillation; π, the ratio of the circumference to the diameter, and $\frac{1}{1+i}$ the ratio of v just before the impact to v just after. Let δt and $\delta \Phi$ denote variations of t and Φ produced by the impact. Then we have, from the common theory of the pendulum—

$$t = \frac{T}{\pi} \text{ arc tan } \frac{\varphi \pi}{v T}$$

$$\Phi = \sqrt{\frac{v^2 T^2}{\pi^2} + \varphi^2}$$

In these equations we are to multiply v by $(1 + i)$ and subtract from the products the above unchanged values to obtain δt and $\delta \Phi$. Developed by Taylor's theorem, and neglecting all but the first two terms, we have—

$$\delta \Phi = \frac{v^2 T^2}{\Phi \pi^2} i = \Phi \left(\cos \frac{\pi t}{T}\right)^2 i = \frac{\Phi^2 - \varphi^2}{\Phi} i$$

$$\delta t = \frac{\frac{\varphi \pi}{v T}}{\sqrt{1 + \left(\frac{\varphi \pi}{v T}\right)^2}} i = \frac{T}{\pi} \sin \frac{t}{T \pi} \cdot i = \frac{T}{\pi} \sqrt{1 - \frac{\delta \Phi}{\Phi i}} \cdot i = \frac{T}{\pi} \frac{\varphi}{\Phi^2 - \varphi^2} \delta \Phi = \frac{T}{\pi} \frac{\varphi}{\Phi} i$$

The quantity i is twice the ratio of the virtual mass of the lever to the sum of those of pendulum and lever. By the virtual mass, I mean the square of the moment of the momentum divided by the moment of inertia. It is safe to say that i does not exceed $\frac{1}{1000}$. And as $\frac{\varphi}{\Phi}$ can easily be reduced to $\frac{1}{20}$, the effect of the resistance can hardly in ten vibrations be perceptible. However, its amount may be calculated by observing φ and $\delta \Phi$.

It will be observed that the resistance shortens the time of oscillation if the impact occurs while the pendulum is moving upward, and lengthens it in the reverse case. Hence, there would be no accumulation of the effect in ten transits over what there would be in two, were it not for the thickness of the agate.

The following results of successive series of 298 swings each, measured with the above-described instrument, by ten transits every five minutes, are a fair specimen of the results obtained.

APRIL 8.

Heavy end up.	Heavy end down.
299ˢ. 9463	299ˢ. 9162
299 . 9436	299 . 9153
299 . 9457	299 . 9147
299 . 9427	299 . 9129
299 . 9439	299 . 9132

APRIL 7.

Heavy end down.	Heavy end up.
299ˢ. 9215	299ˢ. 9549
299 . 9176	299 . 9552
299 . 9167	299 . 9564
299 . 9179	299 . 9513
299 . 9176	299 . 9525

The weights to be assigned to successive intervals of a set of 5 are 5, 8, 9, 8, 5, and this gives for April 8—

$$\text{Heavy end up} \quad T_2 = 1^s.006525 \; T_2^2 = 1.013093$$
$$\text{Heavy end down} \; T = 1.006424 \; T^2 = 1.012889$$
$$T^2 \text{ (corr'd for resistance of air, etc.)} = \frac{39\,T_1^2 - 17\,T_2^2}{22} = 1.012731$$

For April 7—

$$T_1 = 1.006436 \; T^2 = 1.012913$$
$$T_2 = 1.006558 \; T_2^2 = 1.013159$$
$$T^2 \text{ (corr'd)} = 1.012731$$

This is expressed in chronograph-seconds. The results of the two days are identical to the ast figure.

APPENDIX No. 16.

TERRESTRIAL MAGNETISM.

INSTRUCTIONS FOR MAGNETICAL OBSERVATIONS. BY CHARLES A. SCHOTT, ASSISTANT IN THE UNITED STATES COAST SURVEY.

[Reprinted with additions from Appendix No. 14, Report of 1872.]

The measure of the magnetic force at any place on the earth's surface comprises the determination of its direction with reference to the planes of the meridian and of the horizon and of the value of the intensity with reference to a fixed standard adopted as the unit of force.

Observations of this kind are known as absolute measures, and are made with instruments specially designed for the purpose. They are the only ones here considered Some remarks will be made on relative measures. For differential measures, usually made at permanent or fixed observatories, and employing instruments altogether different in principle and construction from those mentioned above, the reader may be referred to observations made at Girard College, Philadelphia, between 1840 and 1845, by Dr. A. D. Bache,* and at Key West, Fla., between 1860 and 1866, by Prof. W. P. Trowbridge, assistant in the Coast Survey, and Mr. S. Walker.†

To the scientist, the measures of the direction and of the intensity are of equal importance; in fact, they are closely connected in theory. To the surveyor and navigator, however, the horizontal direction or magnetic declination (variation of compass) is of special interest. Surveyors are frequently called upon to retrace old magnetic courses, which requires a knowledge of the present declination and of the law of secular change.‡ Navigators are constantly under the necessity of converting proposed true bearings into corresponding magnetic bearings, or *vice versa*. We shall here consider only those instruments and methods of observation designed for use on land, and which admit of far greater accuracy than any observations which can be made on board ships. In the latter case, moreover, the intensity observations are not absolute, but relative to some shore station.

We shall first exhibit the measure of the two components of the direction, viz, the declination (or the direction of a horizontal magnetic needle) and the inclination or dip (or the direction of a vertical magnetic needle), and conclude with the measure of the horizontal and vertical components of the total magnetic intensity.

1. DETERMINATION OF THE MAGNETIC DECLINATION.

The magnetic declination at any place, being the angle contained between the astronomical and magnetic meridians, requires for its measure two distinct operations, namely: The determination of the astronomical meridian, which is generally done by means of a theodolite, and the determination of the magnetic meridian (at a given epoch) by means of the declinometer (or unifilar magnetometer). The former of these planes is fixed, the latter variable, and the observations may have for their object the determination of the declination at various hours of the day, or its mean value for any one day, month, or year.

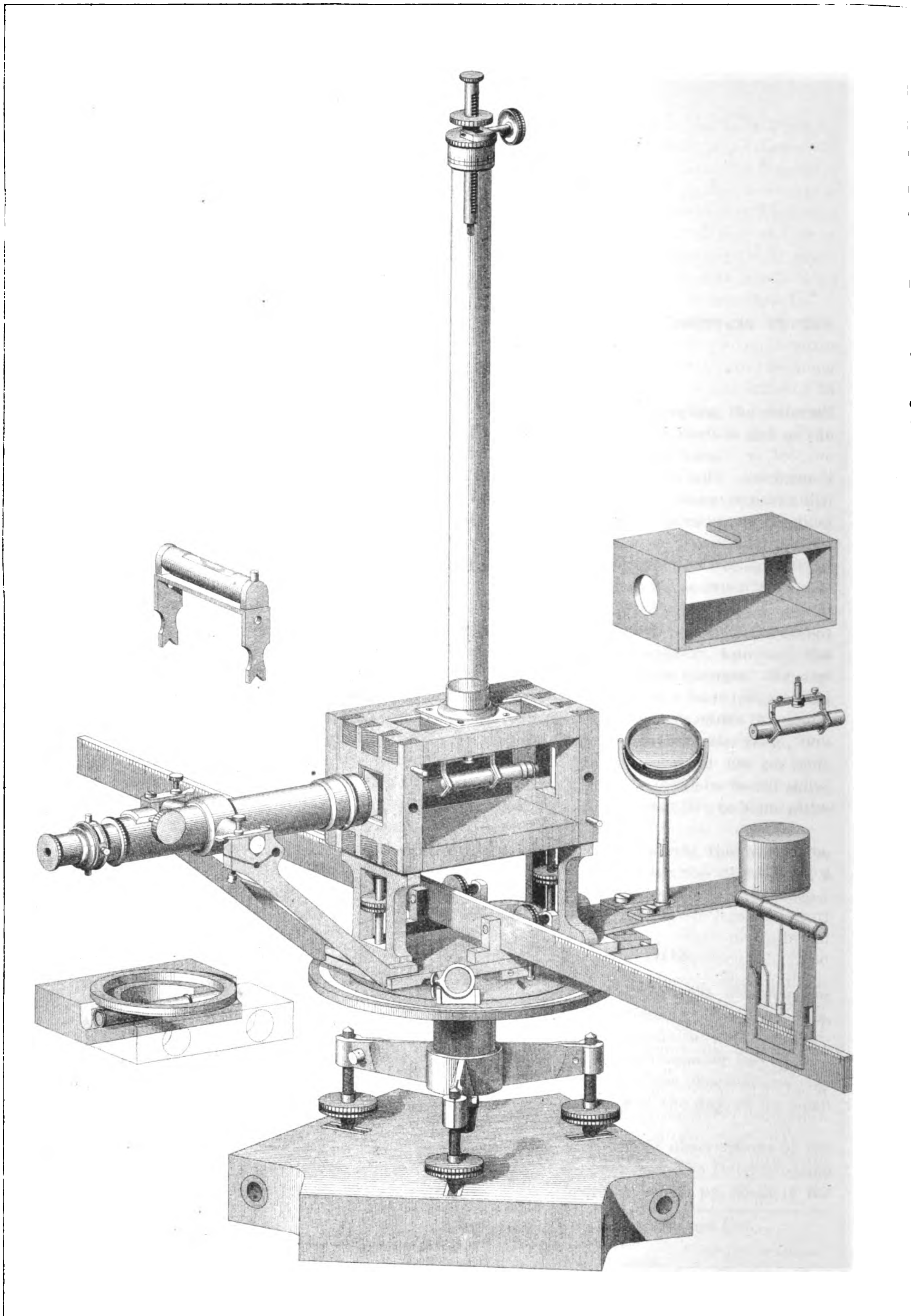
Respecting the determination of the astronomical meridian by means of observations of the azimuth of the sun or of a star, full information will be found in the paper on "The Determination of an Astronomical Azimuth," in Coast Survey Report for 1866, Appendix No. 11, pp. 86–99;§ the

* Reduction and Discussion, in XII parts; Coast Survey Reports of 1859, 1860, 1862, 1863, and 1864.

† Coast Survey Report of 1874, Appendix No. 9. Discussion by Charles A. Schott.

‡ Coast Survey Report of 1874, Appendix No. 8. New discussion by Charles A. Schott.

§ Reprinted in 1876 under the title "Professional Papers. Determination of Time, Latitude, and Azimuth."



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example of observations and reduction given at the end of that paper is taken from a record made in connection with magnetic work. It may be stated that a determination of the meridian which is correct within 1′ fully suffices for magnetic work in general, since it is difficult to determine the magnetic meridian within the same limit, on account of its continued fluctuations. We shall suppose that the azimuth of some mark (any convenient distant object) is known, and that we have merely to find the magnetic azimuth of this mark in order to obtain the declination, which is generally distinguished by a + sign if the magnetic meridian is west of the true north meridian, and by a — sign if east of it. These signs apply to the northern as well as the southern hemisphere.

Adjustment of the declinometer.—A station having been selected, apparently free from local magnetic attraction, the instrument is mounted with the sides of the box, containing the magnet, directed nearly north and south (magnetic), which may be conveniently done by means of a pocket-compass; the instrument must be leveled and the theodolite or telescope adjusted.* In that form of construction of the instrument † which has the magnet-box mounted over the azimuth-circle, the observer may face either the north or south end of the magnet; but in the more complete form of the magnetometer, with attached theodolite, the observer would better face the north end of the magnet, in order to admit more readily of observing the sun for time and azimuth (also for latitude if needed). The change, if desired, can be made by exchanging the lens and plane-glass of the collimator-magnet; but if the same magnet is also used for the intensity-determination, it must *not* be disturbed after the constants have once been determined.

The motion of the magnet is controlled by the observer by means of a small piece of magnetized steel (a small screw-driver, for instance), its magnetism (at its free end) being the same as that of the end of the magnet facing the observer, so as to repel it when brought near. It must neither be too strong, nor be brought too close to the magnet, otherwise the position of the magnetic axis might be disturbed. The suspension-tube should carry at its top a rack and pinion to admit of an easy vertical movement of the magnet. With a piece of cloth at the bottom of the box, the magnet can be let down, and come to rest, by friction, on the fibers of the cloth, and can then be raised and quickly steadied by the magnetized screw-driver, all without opening the box, which in windy weather must be avoided. The sides of the box, if of glass sliding in grooves, must have pasteboard covers to darken it, and the width of the slit facing the mirror must be specially regulated for the best definition of the scale; the shade placed over the object-end of the telescope should nearly touch the box, in order that all stray light may be excluded. The special adjustments to be made are the following:

Suspend the torsion-cylinder, which is of the same weight precisely as the magnet, and take out the twist of the suspension-fibers, of which there should not be more than are absolutely needed to support the weight without risk of breaking—say about 4 or 6 for the older heavy magnets, and 1 or 2 for the light ones. With the aid of the rack-motion and the friction on the cloth, the whole turns of twist are readily taken out, and then the line of detorsion must be placed in the magnetic meridian, in which position the axis of the torsion-weight must be parallel with the side of the box.‡ In packing, the suspension should be kept free of twist, so that at any new station only the small changes developed in the twist need attention. The weight should be removed, the magnet suspended, and the telescope pointed nearly to the middle of its scale, or to the axis of the magnet. The axis of the collimator and the line of collimation of the telescope should then be, as nearly as possible, in the same straight line. To render the scale distinct, the telescope must be set to sidereal focus. The azimuth-circle is then read; the reading, when pointing to the mark,§ having previously been recorded. The relative position of the theodolite and magnet is, of course, invariable, both being supported by the same stand.

The scale-reading of the magnetic axis of the collimator is determined by readings with scale erect and inverted, as shown in the following example:

* See annexed paper on "The Adjustment of the Portable Alt-azimuth Instrument."

† Known as the Theodolite Magnetometer.

‡ This process may require repetition until the observer is assured that there is no torsion when the collimator-magnet is suspended.

§ The best position of the mark is in or near the horizon.

Observation for axis of magnet A_1.

Magnet.	Scale-reading. Left.	Scale-reading. Right.	Mean.	Means of 1 and 3, 2 and 4, &c.	Axis.
					d.
E.	11.0	13.0	12.00		
I.	5.7	7.5	6.60	12.00	9.30
E.	10.9	13.1	12.00	6.55	9.28
I.	5.6	7.4	6.50	12.05	9.28
E.	11.5	12.7	12.10	6.50	9.30
I.	5.7	7.3	6.50	12.07	9.29
E.	11.3	12.8	12.05		
				Mean	9.29

NOTE.—It is recommended to make these observations about the epoch of the day when the magnet is nearly stationary, between 7 and 8 a. m., from May to September, inclusive; in March, April, and October about 8 a. m., and in January, February, November, and December about 9, also about 1½ p. m. in any month and in any part of North America.

The angular value of a division of the scale is determined by successive pointings on the principal divisions, and noting the corresponding readings of the azimuth-circle, and repeating the operation in the reverse order. With that form of the instrument which has the box of the magnet connected with the azimuth-circle, the combination of the results will correct for change of declination during the measures, but a small correction for torsion may be needed; for the other form of construction the magnet may be fastened in its normal position during the scale-measures. The usual value of a scale-division is between 1′ and 3′, and tenths may be estimated. It is only for those instruments which give primarily the amount of deflection, in the intensity-measures, expressed in scale-divisions, that an accurate determination of the scale-value is needed.

Determination of scale-value of magnet C_{16}.

Scale.	Theodolite-circle, mean of two readings.			Value of eighty divisions, 10–90, 20–100, &c.		
d.	°	′	″			
10	159	04	25			
20	158	36	30			
30	158	08	15			
40	157	40	35			
50	157	12	35			
60	156	44	30			
70	156	17	05			
80	155	49	00	°	′	″
90	155	21	15	3	43	10
100	154	52	30		44	00
110	154	24	45		43	30
120	153	57	30		43	05
130	153	28	20		44	15
140	153	00	50		43	40
150	152	33	00		44	05
160	152	04	30		44	30
	Mean			3	43	47

Hence one division of scale = 2′.797.

NOTE.—If the number of pointings is odd, instead of even, as above, the mean reading corresponding to the *middle* division must be found and subtracted from each separate value. The differences so obtained must be added, and their sum (irrespective of sign), when divided by the corresponding number of scale-divisions, will furnish the desired value.

For an example of the amount of torsion, as measured from four twists of 90° each, see "Observations for Intensity-Oscillations" further on. Moistening the fibers with a drop of glycerine will greatly reduce and equalize the torsion.

It appears from observations of the daily fluctuation of the declination that the mean of the extreme easterly and westerly positions in any one day approaches nearly (within half a minute) to the mean position of the day, as derived from hourly observations continued day and night. Since corrections to observed declinations to refer them to the mean of the day are generally very unsatisfactory, it is recommended to observe the declination for any one day at the epochs of the eastern magnetic elongation and of the western magnetic elongation, and to take the mean position as representing the declination for that day. The epochs of extreme positions, as observed at Philadelphia, Washington, and Key West, apply, with comparatively small changes, to nearly all places within the United States, and may be stated to be as follows: Referring to the north end of the magnet, the morning eastern elongation occurs, on the average, from May to September, inclusive, about 7½ a. m.; in March, April, and October, about 8 a. m.; in November, about 8½ a. m.; and in December, January, and February, about 9 a. m.; earliest time in August, about 7¼ a. m.; latest in January, about 9 a. m. These epochs, however, are subject to great fluctuations and cannot be depended upon in any one case within one hour, and frequently they cannot be recognized at all, either on account of the small range of the daily fluctuation—the amount of which in winter is but one-half, nearly, of the amount in summer—which is easily disguised by small irregularities, or on account of disturbances, which reach their maxima in September and October, and generally are more predominant in winter than in summer. The afternoon western elongation occurs, on the average, about 1¼ p. m. from May to November, inclusive, and about 1¾ p. m. in the remaining months; also, earliest in September—some minutes before 1 p. m.—and latest in January, about 1¾ p. m. The afternoon epoch is subject to less fluctuation than the morning epoch.

The observations for declination, which consist in noting the scale-readings, may be made, say, every ten minutes or quarter of an hour, commencing at a sufficiently early time in the morning to make sure of preceding the eastern elongation. When this phase is fairly passed, and consequently the north end of the magnet has commenced its westerly motion, the observations may be discontinued, to be resumed again shortly after noon for the second epoch, and to include the western elongation, as shown in the following example:

MAGNETIC DECLINATION.

Station, Washington, D. C. Date, June 15, 1871. Instrument, declinometer No. 7. Observer, C. A. S. Mark reads at $6^h\ 10^m$, 242° 50′.5 and 62° 49′.5. Line of detorsion, 276°. Magnet A suspended, scale erect.—Azimuth-circle set to 244° 25′.0 and 64° 24′.5.

Time.		Scale-readings.		Mean.	Remarks.
		Left.	Right.		
A. M.					
h.	*m.*	*d.*	*d.*	*d.*	
6	30	11.0	12.8	11.90	Removed torsion-weight at $6^h\ 15^m$ and suspended magnet.
	45	11.8	12.2	12.00	
7	00	12.0	12.3	12.15	
	15	12.2	12.5	12.35	
	30	12.4	12.5	12.45	Maximum.
	45	12.3	12.5	12.40	
8	00	12.1	12.3	12.20	Suspended torsion-weight after this observation.
P. M.					
h.	*m.*	*d.*	*d.*	*d.*	
0	15	5.9	6.9	6.40	Before commencing afternoon series turned torsion-circle to 264°; azimuth-circle as before.
	30	6.0	6.6	6.30	
	45	6.2	6.5	6.35	
1	00	6.2	6.3	6.25	Minimum.
	15	6.2	6.3	6.25	Minimum.
	30	6.3	6.7	6.50	

Pointing on mark: 242° 50′.0 and 62° 49′.5.

	d.	*d.*
Mean reading of E. and W. elongations.....	9.35,	and difference of readings 6.20
Axis of magnet reads......................	7.30	
Reduction to axis.........................	+2.05=	5′.0
Azimuth-circle reads......................		244° 24′.8
Magnetic meridian reads.................		244° 29′.8
Mark reads................................		242° 49′.9
Mark, west of north.......................		4° 36′.1 ± 0′.1
Astronomical meridian reads.............		247° 26′.0
Magnetic declination......................		+2° 56′.2
Reduction to mean of day..................		+ 0′.2
Resulting magnetic declination, June 15, 1871.........		2° 56′.4 W.

We have, also, on this day the daily range 15′.1, and the turning hours about $7^h\ 30^m$ a. m., and $1^h\ 05^m$ p. m. Unless time be wanting it is customary to observe for declination, as above, on three, generally consecutive, days.

The observer's attention should be specially directed to the frequent examination of the line of detorsion, since every change in the temperature or moisture of the air is apt to develop twist, which, if not removed, will injure the accuracy of the observations.

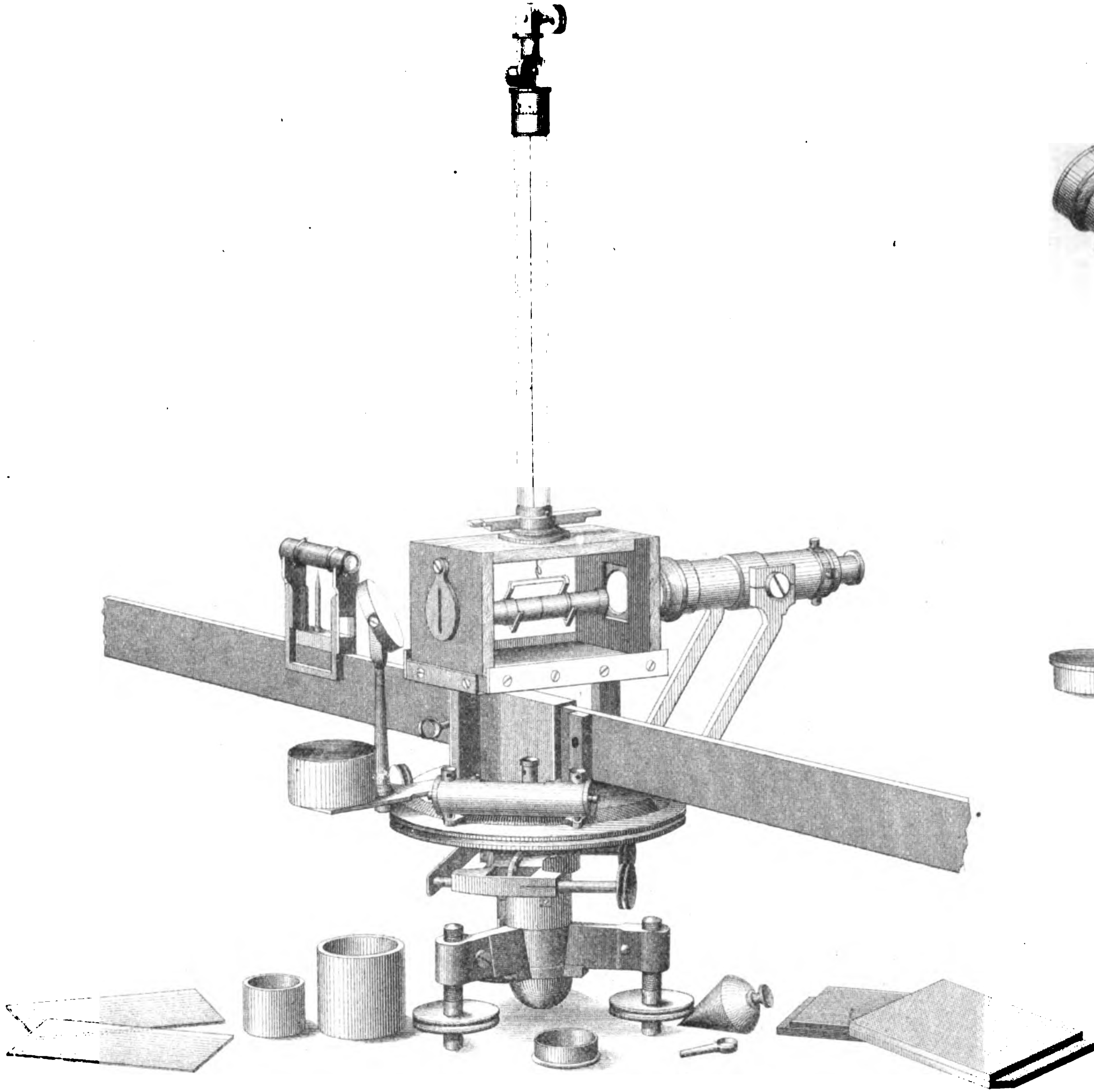
MEMORANDUM ON THE ORDINARY ADJUSTMENTS OF THE THEODOLITE, OR PORTABLE ALT-AZIMUTH INSTRUMENT, FOR THE MEASUREMENT OF HORIZONTAL AND VERTICAL ANGLES, AND FOR ASTRONOMICAL OBSERVATIONS.

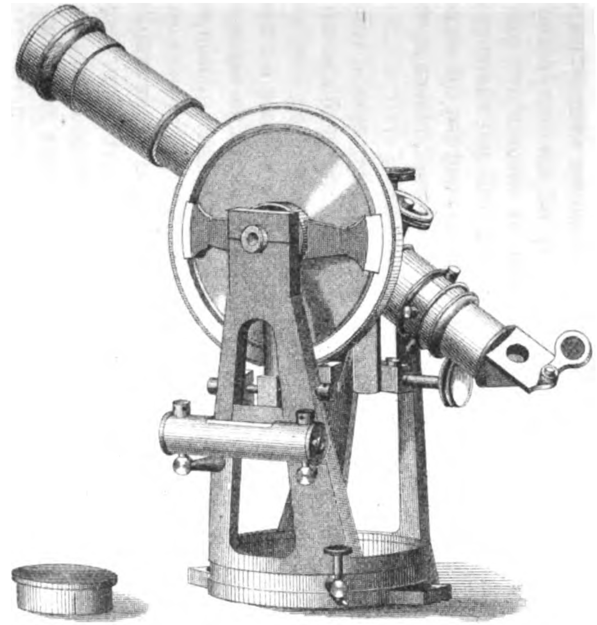
The various operations for placing the parts of a theodolite in proper condition for observing in order to eliminate, as far as possible, sources of error arising from instrumental defects, may be briefly stated as follows:

To adjust the levels.—After properly setting up the stand, clamping it, and mounting the instrument, adjust the most sensitive of the levels attached to it by bringing two of the foot-screws of the theodolite in line with the direction of the level, and, after leveling, turn the azimuth-circle 180°, correct any defect, one-half by means of the foot-screws (always working them in opposite directions), the other half by means of the adjusting-screws of the level; turn the circle back to first position and repeat the correction as before as often as may be necessary. If, during this operation, we turn the circle once or twice at right angles to the former position, and make the bubble play in the middle by turning the third foot-screw of the theodolite, there may be no need of using the *graduation* to effect the adjustment of the level, the turning of 180° by estimation being sufficient to effect the purpose. If there is a second level attached to the circle at right angles to the former, it may be adjusted like the first, or, more expeditiously, by placing it in the same direction as the first (when in adjustment), and correcting any defect by its correcting-screw. Circular levels must be adjusted upon the same principles; they are, however, generally of inferior accuracy.

To place the axis of the azimuth-circle vertical.—By means of the adjusted level we place the vertical axis in position by leveling the instrument with the two foot-screws parallel with the direction of the level, and then turning the circle 90°, and bringing the bubble again to the middle by turning the third foot-screw. The verticality of the axis is tested by the steadiness of the bubble in the middle of the tube when the instrument is slowly revolved in azimuth.

To adjust the threads of the telescope.—Place the threads in the focus of the eye-piece where their best definition is obtained, and test the position by pointing to a distant well-defined object to which the focus of the object-glass is adjusted for distinct vision; and if by moving the eye sidewise the object appears to move off the thread or pointing in the same direction as the eye, the diaphragm must be slightly pushed in, and pulled out in the contrary case. If there are two threads intersecting in the middle of the field at right angles, the vertical thread may be set vertical by sighting a plumb-line suspended at a proper distance, or the vertical edge of a house may be used instead.





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The whole diaphragm (after loosening its four screws) is to be turned around the optical axis to effect the coincidence. The preceding adjustment must not be disturbed. The horizontal thread may also be tested by pointing to an object, and then turning the azimuth-circle, previously set horizontal, when the object should remain bisected; it may also be effected by pointing on the sea-horizon.

To adjust the line of collimation of the telescope.—If the horizontal axis of the telescope admits of being reversed in its supports, a distant object is pointed to; and if, after reversal of the axis in its V's, the pointing remain perfect, the line of collimation is at right angles to the axis; if not, half of the difference is to be corrected by the azimuth-screw and half by the two adjusting-screws of the diaphragm (its former adjustsments remaining undisturbed). If the axis does not admit of reversal in the V's, it must be reversed by reversal of the circle, using the graduation; and if the second reading, after reversal, should differ from it a little more or less than 180°, the difference must be corrected as before, and the process is to be repeated until the readings, direct and reversed, differ by 180° exactly. For greater accuracy, we may use a collimator instead of the distant object. In some instruments the telescopes are mounted on one side instead of in the middle of the azimuth-circle; their collimation may be corrected by two distant marks separated exactly by twice the eccentricity of the axis of the telescope from the vertical axis of the theodolite. The process of adjustment is then the same as described, only changing the mark with a change of the telescope from one side to the other. For oblique intersections of the threads, the point of intersection must be brought into the optical axis of the telescope, the adjustment for collimation being the same as described. In this case, a collimator with a vertical thread is used to advantage.

To place the horizontal axis of the telescope in position.—This axis must be at right angles to that of the azimuth-circle, and if in position or horizontal the line of collimation, when revolving the telescope, must pass through the zenith of the observer. It is effected by placing an adjusted level on the axis and correcting the whole error with the adjusting-screw of the pivot. If the level is fixed or uncorrected, it must be adjusted at the same time with the axis by leveling and then turning the azimuth-circle 180°, and correcting one-half of the defect by the pivot-screw and the other half by the level-screw. The process also requires repetition for its perfection.

The instrument is now ready for the measurement of horizontal angles, either by "directions" or by "angles," with or without repetitions, according to the construction of the instrument or the requirements of the case. In either method one-half of the measures must of course be made with "circle direct," the other half with "circle reversed" by 180°, which process corrects the angles for any *remaining defect*, after adjustment in the verticality of the axis, in the height of the V's, in the form of the pivots, and in the collimation. If the telescope is placed eccentrically, this reversal will at the same time refer the resulting measures to the axis of the circle, or, what should be the same, to the vertical of the station.

In repeating angles it suffices to record the readings of the circle at the commencement and at the end of the operation, the telescope being reversed after half the number of repetitions are secured. During the reversal of the telescope the circles remain firmly clamped until after the new pointing is made. With non-repeaters, or when used as such, the records for telescope "D" and for telescope "R" are kept separate.

The eccentricity of a circle is corrected by taking the mean of the readings of two opposite verniers or microscopes, or the mean of the readings of any number of verniers or microscopes, provided they are so placed as to divide the whole circumference into equal parts.

To adjust the level required for vertical measures.—The measures of vertical angles depend, among other things, on the accuracy of the adjustment of the level. It is effected by leveling and reversing the azimuth-circle 180°, using one of the level-screws for correction, provided the former adjustment of the vertical axis has not been disturbed. This level may either be attached to the azimuth-circle or to the arms carrying the verniers or microscopes of the altitude-circle; in the former position it is of course placed parallel to or in the plane of the altitude-circle.

The instrument is now in the proper condition for the measure of vertical angles. Generally, *double* zenith-distances are measured, by means of which the reading of the zenith (or nadir) point on the circle becomes known, and consequently also the reading of the horizon. If there is any index-error, it may either be corrected (many instruments admit of such a correction) or it may be

allowed for as a constant when single altitudes are measured. This index-error is of no consequence if double zenith-distances are taken (involving positions, circle right and circle left).

Owing to the great diversity in the construction of theodolites, depending upon the particular use and the degree of perfection required of them, rules cannot be given to apply alike to all constructions; but the preceding notes will suffice in all ordinary cases of the use of the portable instrument. To test the graduation, its eccentricity, systematic and irregular errors; to adjust the reading-microscopes (for run and focus); to test the coincidence of the two horizontal axes, also of the two vertical axes, *in repeating-instruments;* to examine the perpendicularity of the planes of the circles (graduation) to their respective axes; to measure the flexure of the telescope, and other circumstances, will require the attention of the observer when engaged in the more refined geodetic or astronomical use of the alt-azimuth.

The principle of repetition applies most advantageously when the optical power of the telescope exceeds relatively the accuracy of the graduation; in other words, when the pointing-error is less than the graduation-error. If the optical power is inferior, or not commensurate with the perfection of the graduation, we may still save time by using this method, the number of readings being less; or it may be utilized by giving *position* to the instrument, to spread the readings over the graduation. Although the principle of repetition is an elegant one, in practice it has been found frequently to introduce a new source of error, namely, a constant or slowly variable error depending on friction, the imperfection of the clamping, and general instability of the instrument. Unless the clamps are perfect, repeating will introduce a constant error, which cannot be eliminated from the result by the forward and backward movement of one circle upon the other, and the observer should carefully test whether or not his pointing will be preserved when repeatedly clamping and unclamping; this especially applies to the clamps upon which the movement of the inner circle depends (for repeaters). The clamps should never be at the circumference of the circle of graduation, but near the axis, unless for inferior instruments. Before observing its general stability, the clamping apparatus should be examined as well as the proper amount of friction of the moving parts and the balancing of weights. Instruments with light spokes to their azimuth-circles (though they may otherwise be high or thick enough), and having a heavy superstructure (vertical circle and counterpoise), frequently show so much flexure or spring as to affect injuriously all horizontal measures, while full thin plates are not liable to this defect.

Azimuths in connection with the magnetic declination, where an accuracy of a fraction of a minute suffices, may be obtained with a small alt-azimuth instrument (say of four or five inches diameter). Supposing the latitude given, but the time only approximately known, the sun's zenith-distance and azimuth may be observed as follows: reading of mark, three readings of the sun's upper and first limb, noting the chronometer-time at contacts; instrument reversed, three readings of the sun's lower and second limb, reading of mark.

Let $h =$ altitude, corrected for refraction, parallax (semi-diameter and dip, if necessary), and $p =$ the sun's or star's polar distance, then—

$$\tan^2 \tfrac{1}{2} A = \frac{\sin(s-\varphi)\sin(s-h)}{\cos s \cos(s-p)},$$

in which expression $s = \frac{1}{2}(\varphi + h + p)$. If the time should also be desired, it may be computed by

$$\tan^2 \tfrac{1}{2}t = \frac{\cos s \sin(s-h)}{\sin(s-\varphi)\cos(s-p)}, \text{ or by } \tan \tfrac{1}{2}t = \cot \tfrac{1}{2}A \frac{\sin(s-h)}{\cos(s-p)}.$$

If the sun's limb is observed, the correction to the azimuth for reduction to center is $\pm \frac{r}{\sin \zeta}$, where $r =$ sun's radius; whether $+$ or $-$ is to be used, will readily be known in each particular case. t is the hour-angle.

If the local time is known, we may observe Polaris for azimuth and latitude, computing the former by the fundamental formula, in which the azimuth A is counted from the north—

$$\tan A = \frac{\sin t}{\cos\varphi \tan\delta - \sin\varphi \cos t},$$

and the latter by—

$$\varphi = h - p\cos t + \tfrac{1}{2}\sin 1'' (p \sin t)^2 \tan h.$$

For greater accuracy, we may observe the star direct and reflected in mercury.

The following two examples will serve to illustrate the methods:

Example of record and reduction.

STATION, WASHINGTON, D. C., IN PARK EAST OF THE CAPITOL.

Sun near prime vertical. August 15, about 8h a. m., 1856. Observer, C. A. S. Instrument, five-inch magnetic theodolite. Sidereal chronometer.

Chronometer-time.	Horizontal circle. A.	Horizontal circle. B.	Vertical circle. A.	Vertical circle. B.	Temperature.
SET I.	⊙'s upper and first limb. Telescope D.				73° Fahr.
h. m. s.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
5 02 53.0	25 24 30	205 24 30	61 56 00	61 56 00	(Bar. 30 in., assumed.)
05 34.0	25 50 45	205 51 30	61 24 30	61 25 00	
06 55.5	26 04 30	206 05 15	61 08 45	61 09 30	
	⊙'s lower and second limb. Telescope R.				
5 09 12.0	205 54 15	25 54 00	61 19 30	61 18 30	
10 32.0	206 07 15	26 06 45	61 04 00	61 03 00	
11 42.0	206 18 30	26 18 15	60 50 00	60 49 45	
SET II.	⊙'s lower and second limb. Telescope R.				
5 13 22.0	206 35 30	26 35 30	60 30 45	60 30 15	
14 32.0	206 47 30	26 47 30	60 17 30	60 17 00	
15 36.5	206 58 30	26 58 00	60 05 15	60 04 30	
	⊙'s upper and first limb. Telescope D.				
5 17 07.0	27 47 30	207 48 15	59 11 45	59 12 00	
18 16.5	28 00 00	208 00 30	58 57 45	58 58 00	
19 19.0	28 10 15	208 10 30	58 45 30	58 45 15	
SET III.	⊙'s upper and first limb. Telescope D.				
5 20 44.0	28 25 00	208 25 00	58 29 00	58 29 30	
22 01.5	28 37 45	208 38 15	58 14 45	58 14 30	
25 26.5	29 13 30	209 14 00	57 36 00	57 35 45	
	⊙'s lower and second limb. Telescope R.				
5 27 32.5	209 01 30	29 00 30	57 48 00	57 47 30	
28 39.5	209 12 45	29 12 15	57 34 30	57 34 15	
30 01.0	209 27 00	29 26 30	57 19 15	57 18 30	78° Fahr.

$\phi=38°\ 53'\ 18''$. $\lambda=5^h\ 08^m\ 01^s.0$ west of Greenwich.

	Mean chronometer-time.	Mean reading horizontal circle.	Mean reading vertical circle.	Correction for parallax in altitude and refraction.	Corrected ζ.
	h. m. s.	° ′ ″	° ′ ″	′ ″	° ′ ″
Set I.......	5 07 48.1	25 56 40	61 17 02	+ 1 34	61 18 36
Set II.......	5 16 22.2	27 23 17	59 38 00	+ 1 27	59 39 27
Set III......	5 25 44.1	28 59 30	57 50 07	+ 1 21	57 51 28

	Set I.	Set II.	Set III.
	° ′ ″	° ′ ″	° ′ ″
ϕ	38 53 18	38 53 18	38 53 18
h	28 41 24	30 20 33	32 08 32
p	76 04 27	76 04 37	76 04 44
A (from north)	95 06 06	96 32 34	98 08 54
Circle reads	25 56 40	27 23 17	28 59 30
South meridian reads	110 50 34	110 50 43	110 50 36

Hence the north meridian reads, 290° 50′ 38″.

We shall also find the chronometer slow of sidereal time 16^m $05^s.1$, the results by the sets agreeing within a fraction of a second.

Example 2.—Station, Magnetic Observatory, Capitol Hill, Washington, D. C. Polaris near lower culmination. May 23, 1873 (observations made during evening twilight). Observer, C. A. S. Instrument, 2¾-inch Casella theodolite No. 3524; sidereal chronometer Kessels 1287. Noon-ball at United States Naval Observatory dropped on May 17 at 4^h 55^m $32^s.5$, and on May 24 at 5^h 23^m $15^s.5$ chronometer-time. The latitude of the magnetic station is 38° 53′.1 and the longitude $11^s.6$ east of the United States Naval Observatory.

Object.	Circle.	Chronometer-time.	Azimuth-circle. A.	Azimuth-circle. B.	Vertical circle. A.	Vertical circle. B.
		h. m. s.	° ′	° ′	° ′	° ′
Mark	R.		0 00	180 03	[177 01]	[357 02]
Mark	L.		180 05	0 03	[3 00]	[182 57]
Polaris	L.	Dir. 13 16 46	169 58	349 55	37 36	217 39
Polaris	L.	Ref. 24 55	169 59	349 58	322 29	142 24
Polaris	R.	Dir 13 40 20	350 08	170 06	217 30	37 29
Polaris	R.	Ref. 45 37	350 06	170 07	142 23	322 25
Mark	R.		0 02	180 04		
Mark	L.		180 05	0 04		

Star seen through thin clouds, occasionally interfering with observations. Atmospheric pressure, 29.85 inches; atmospheric temperature, 70° Fahrenheit.

Computing for circle left and circle right, separately, we find—

	h. m. s.	h. m. s.		° ′ ″
Chronometer-time	13 20 50	13 42 59	Also δ =	88 37 44
Chronometer-correction	− 1 13 36	− 1 13 36	p =	1 22 16
Sidereal time of observation	12 07 14	12 29 23		
α Polaris	1 11 28	1 11 28		
t	10 55 46	11 17 55		
	° ′	° ′		
Also h observed	37 35.5	37 32.8		
Correction for refraction	− 1.2	− 1.2		
h	37 34.3	37 31.6		

With these data we find—

A = 0° 28′ 42″ and 0° 18′ 57″

Star reads, 169° 57′.5 and 170° 06′.8

Meridian, 170° 26′.2 and 170° 25′.8 Mean, 170° 26′.0

Mark reads, 180° 03′.2

Mark E. of N., 9° 37′.2 ± 0′.4

Also, φ = 38° 53′.5 and 38° 52′.5

Latitude, 38° 53′.0 ± 0′.4

The following table will be found useful for correcting or reducing an observation of the declination taken at any time between 6 a. m. and 6 p. m. to the mean of the day (or to the mean of 24 hourly observations). It is, however, only approximate, since the tabular values are slightly variable in the eleven-year or solar-spot cycle; moreover, they are varying irregularly from day to day. For interpolation for any place in the United States we may consider that, roughly speaking, the greater the horizontal force the smaller the tabular values, or the range of the daily variation is inversely proportional to the horizontal force. We have the horizontal force H at Toronto 3.50, at Philadelphia 4.16, and at Key West 6.74, nearly. No notice is taken of the annual inequality, which may amount to about one minute and a half, in maximo.

Solar diurnal variation of the declination at Toronto, Canada, at Philadelphia, and at Key West, Fla

A + sign indicates a deflection of the north end of the magnet to the westward. A − sign, to the eastward.

	6 a. m.			7 a. m.			8 a. m.			9 a. m.			10 a. m.			11 a. m.		
	T.	P.	K. W.	T.	P.	K. W.	T.	P.	K. W.	T.	P.	K. W.	T.	P.	K. W.	T.	P.	K. W.
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January	−0.7	−0.6	+0.1	−1.3	−1.2	0.0	−2.7	−2.1	−1.1	−2.9	−2.5	−2.4	−1.5	−1.6	−2.7	+0.4	+0.3	−1.4
February	−1.6	−1.2	−0.1	−2.0	−1.9	−0.3	−2.9	−2.5	−1.1	−2.8	−2.5	−2.0	−1.5	−1.5	−2.0	+0.5	+0.2	−1.2
March	−2.3	−1.8	−0.8	−3.5	−2.9	−1.9	−4.7	−3.7	−2.4	−4.5	−3.4	−2.2	−2.5	−1.8	−1.4	+0.7	+0.6	−0.1
April	−3.4	−2.6	−1.5	−4.6	−3.5	−2.8	−5.0	−4.0	−3.1	−4.0	−3.4	−2.2	−1.3	−1.5	−1.1	+2.0	+1.1	+0.4
May	−5.2	−3.7	−2.0	−6.0	−4.7	−3.4	−5.8	−4.7	−3.4	−4.2	−3.2	−2.1	−0.6	−0.8	−0.4	+3.1	+1.9	+1.1
June	−5.3	−3.9	−2.2	−6.4	−5.0	−3.5	−6.2	−5.1	−3.6	−4.7	−3.8	−2.4	−1.7	−1.2	−0.9	+2.0	+1.7	+0.9
July	−4.5	−4.2	−2.3	−6.5	−5.4	−3.6	−6.3	−5.4	−3.6	−4.9	−4.0	−2.5	−1.8	−1.5	−0.7	+1.8	+1.5	+0.9
August	−5.2	−4.7	−2.3	−6.9	−5.7	−4.5	−6.9	−5.5	−4.4	−4.8	−3.7	−2.8	−0.5	−0.6	−0.4	+3.1	+2.9	+1.6
September	−3.9	−3.5	−1.8	−5.2	−4.5	−3.6	−4.8	−4.5	−3.6	−3.0	−2.8	−2.3	−0.6	+0.1	−0.4	+3.7	+3.2	+1.5
Octob r	−1.8	−1.3	−0.6	−2.7	−1.7	−1.9	−3.7	−2.2	−2.3	−3.0	−1.9	−1.8	−1.1	−0.8	−0.5	+1.7	+0.8	+0.7
November	−1.3	−1.2	0.0	−1.8	−1.7	−0.5	−2.9	−1.9	−1.4	−2.8	−1.5	−1.7	−1.3	−0.4	−1.3	+1.1	+1.1	−0.3
December	−0.6	−0.7	+0.3	−0.9	−1.0	+0.2	−1.5	−1.4	−0.9	−2.0	−1.6	−2.0	−1.6	−1.1	−2.2	+0.3	+0.3	−1.4

	Noon.			1 p. m.			2 p. m.			3 p. m.			4 p. m.			5 p. m.			6 p. m.		
	T.	P.	K. W.	T.	P.	K. W.	T.	P.	K. W.	T.	P.	K. W.	T.	P	K. W.	T.	P.	K. W.	T.	P.	K. W.
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
Jan	+2.5	+2.3	+0.4	+3.3	+3.4	+1.6	+3.1	+3.3	+1.9	+2.4	+2.5	+1.7	+1.6	+1.5	+1.1	+0.9	+0.9	+0.6	+0.3	+0.6	+0.3
Feb	+2.4	+2.0	+0.1	+3.3	+3.0	+1.1	+3.3	+3.0	+1.5	+2.5	+2.4	+1.4	+1.7	+1.7	+1.1	+1.4	+1.2	+0.8	+0.8	+0.8	+0.5
Mar	+3.7	+2.7	+1.1	+5.2	+3.9	+1.9	+5.4	+3.9	+2.2	+4.8	+3.2	+1.8	+3.4	+2.3	+1.1	+2.2	+1.6	+0.7	+1.1	+1.0	+0.6
Apr	+4.5	+3.6	+1.6	+6.0	+5.1	+2.5	+5.8	+5.2	+2.9	+5.0	+4.3	+2.6	+3.3	+3.0	+1.9	+1.7	+1.8	+0.9	+0.8	+0.9	+0.5
May	+5.2	+4.1	+2.1	+6.3	+5.1	+2.6	+6.1	+4.9	+2.6	+4.8	+3.9	+2.3	+3.1	+2.5	+1.5	+1.3	+1.2	+0.8	+0.4	+0.4	+0.5
June	+4.7	+4.0	+2.1	+6.2	+5.0	+2.6	+6.3	+4.8	+2.8	+5.3	+3.8	+2.5	+3.8	+2.6	+1.7	+1.7	+1.6	+1.0	+0.6	+0.9	+0.5
July	+4.2	+3.9	+1.9	+5.9	+5.3	+2.5	+6.0	+5.4	+2.6	+5.1	+4.5	+2.3	+3.7	+3.3	+1.6	+1.9	+2.0	+1.0	+0.7	+1.2	+0.5
Aug	+6.0	+5.4	+2.7	+7.2	+6.3	+3.2	+6.5	+5.5	+3.2	+5.0	+3.8	+2.4	+2.7	+2.0	+1.5	+1.0	+0.9	+0.7	+0.2	+0.5	+0.4
Sept	+6.3	+5.2	+2.6	+6.4	+5.5	+2.9	+5.4	+4.5	+2.5	+3.4	+3.0	+1.7	+1.2	+1.7	+0.8	+0.4	+0.8	+0.5	−0.1	+0.3	+0.5
Oct	+3.7	+2.6	+1.5	+4.2	+3.2	+1.6	+3.9	+3.0	+1.3	+2.7	+2.2	+1.0	+1.8	+1.1	+0.8	+1.2	+0.3	+0.8	+0.7	−0.4	+0.5
Nov	+3.0	+2.3	+0.7	+3.8	+2.8	+1.2	+3.3	+2.6	+1.1	+2.5	+1.9	+0.9	+1.8	+1.2	+0.6	+1.1	+0.6	+0.2	+0.1	+0.1	0.0
Dec	+1.9	+1.9	−0.1	+3.0	+3.0	+0.9	+3.4	+3.0	+1.4	+2.4	+2.3	+1.4	+1.7	+1.3	+1.0	+0.8	+0.6	+0.5	0.0	+0.1	+0.1

The Toronto results are derived from observations of five years ending June 30, 1848.
The Philadelphia results are derived from observations of five years ending June 30, 1845.
The Key West results are derived from observations of six years ending April, 1866.
For reducing observations to mean of day (24 hours) the signs of the tabular quantities must be *reversed*.

2. DETERMINATION OF THE MAGNETIC INCLINATION.

The inclination, or dip, is measured in the vertical plane passing through the magnetic meridian of the place, and is the angle contained between a horizontal direction and the direction of a magnetic needle moving freely about a horizontal axis directed east and west magnetically. It is measured by means of a dip-circle, and is considered + when the north end of the needle dips below the horizon. Thus in the north magnetic hemisphere the dip will be + and in the south magnetic hemisphere −.

In a plainly-constructed circle, the graduation, which is directly read off at the ends of the

needle is generally not closer than quarter-degrees or ten minutes, and subdivisions are to be estimated.* In the more elaborate instruments,† as used at Kew, for instance, the needle does not swing in the plane of the graduated circle, and the pointing at end marks on the needle is done by the aid of two microscopes, with threads in the focus, and the circle is read off to the nearest minute or half-minute by means of two verniers. The latter construction is advantageous only with well-balanced needles, having as perfectly cylindrical axles as can be made.

To place the dip-circle in the plane of the magnetic meridian, we have two ways, either by the aid of an ordinary long compass-needle, which is supported between the agate plates, or by means of the dipping-needle, which will point vertically in the plane of the magnetic prime vertical. The former method is more expeditious; the latter can always be resorted to, and consists in four readings of the azimuth-circle of the instrument when placed successively in the position: face of circle south (magnetic), with face of needle south and face of needle north; next, face of circle north, with face of needle north and face of needle south; the mean reading $+ 90^\circ$ and $- 90^\circ$ will give the settings of the circle for the measure of the dip. A more precise value will be found if the process is repeated, with the polarity of the needle reversed.

In adjusting the dip-circle preparatory to observing, the following conditions should be attended to, and the observations should be arranged so as to eliminate any small outstanding defects in the perfect condition of the instrument; the instrument must remain level when turned about a vertical axis; the agate or steel plates supporting the needle should have their upper surfaces level, should be of equal height, and a horizontal tangent-plane should pass below the center of graduation of the circle at a distance equal to the radius of the axle of the needle. The zero graduation of the circle should lie in a horizontal plane; also the plane of the suspended needle and that of the circle should be truly vertical; and, finally, the prolongation of the axle of the needle should pass through the center of graduation. For instruments provided with microscopes, the following additional conditions should be satisfied: The microscopes must be focused and collimated; their threads should be 180° apart, and if produced should pass through the center of graduation.

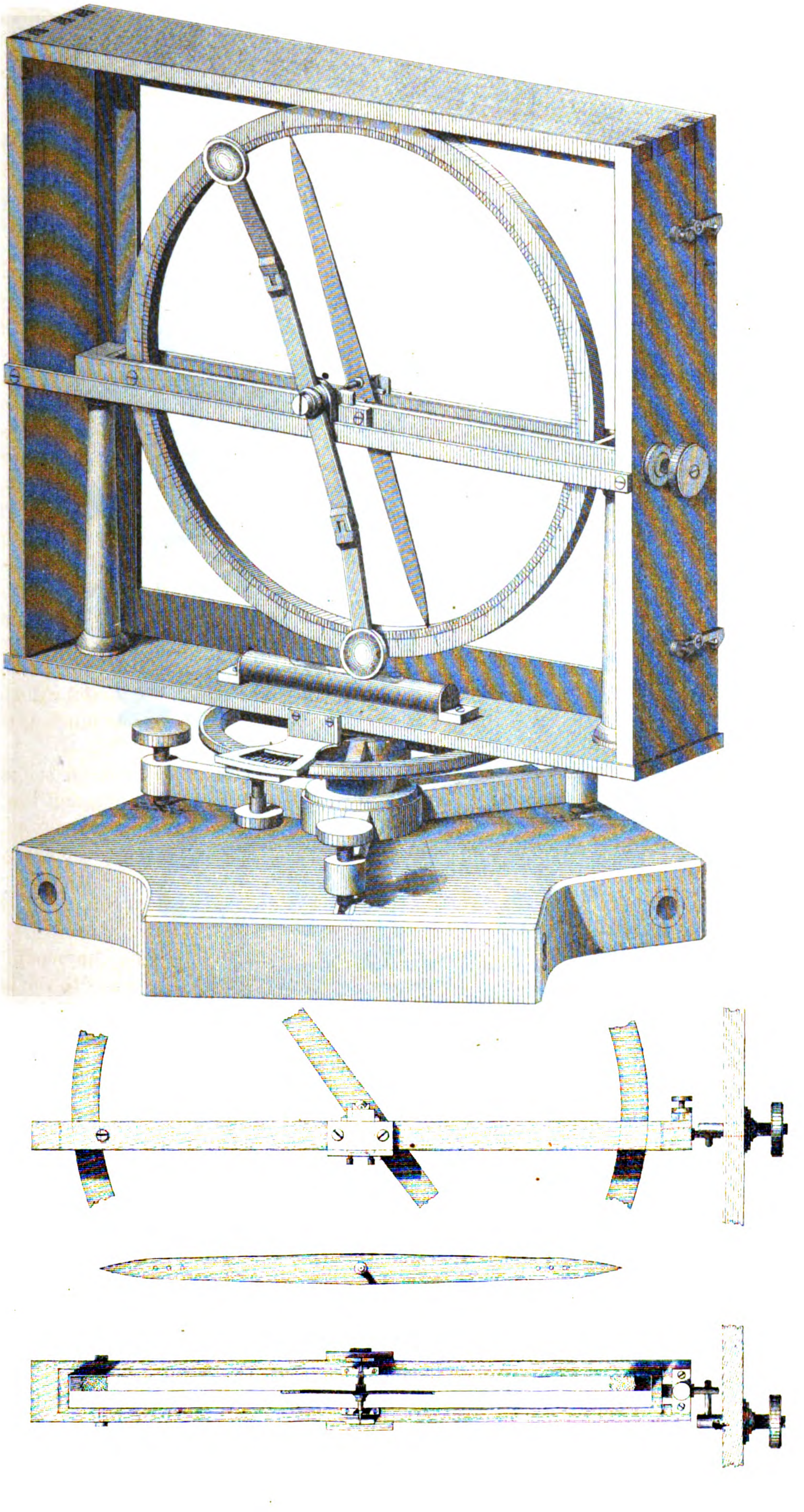
The needles, before magnetization, should balance perfectly, and those intended for the relative measure of total intensity, according to Dr. Lloyd's method, should be guarded as much as possible against any change in their magnetism.

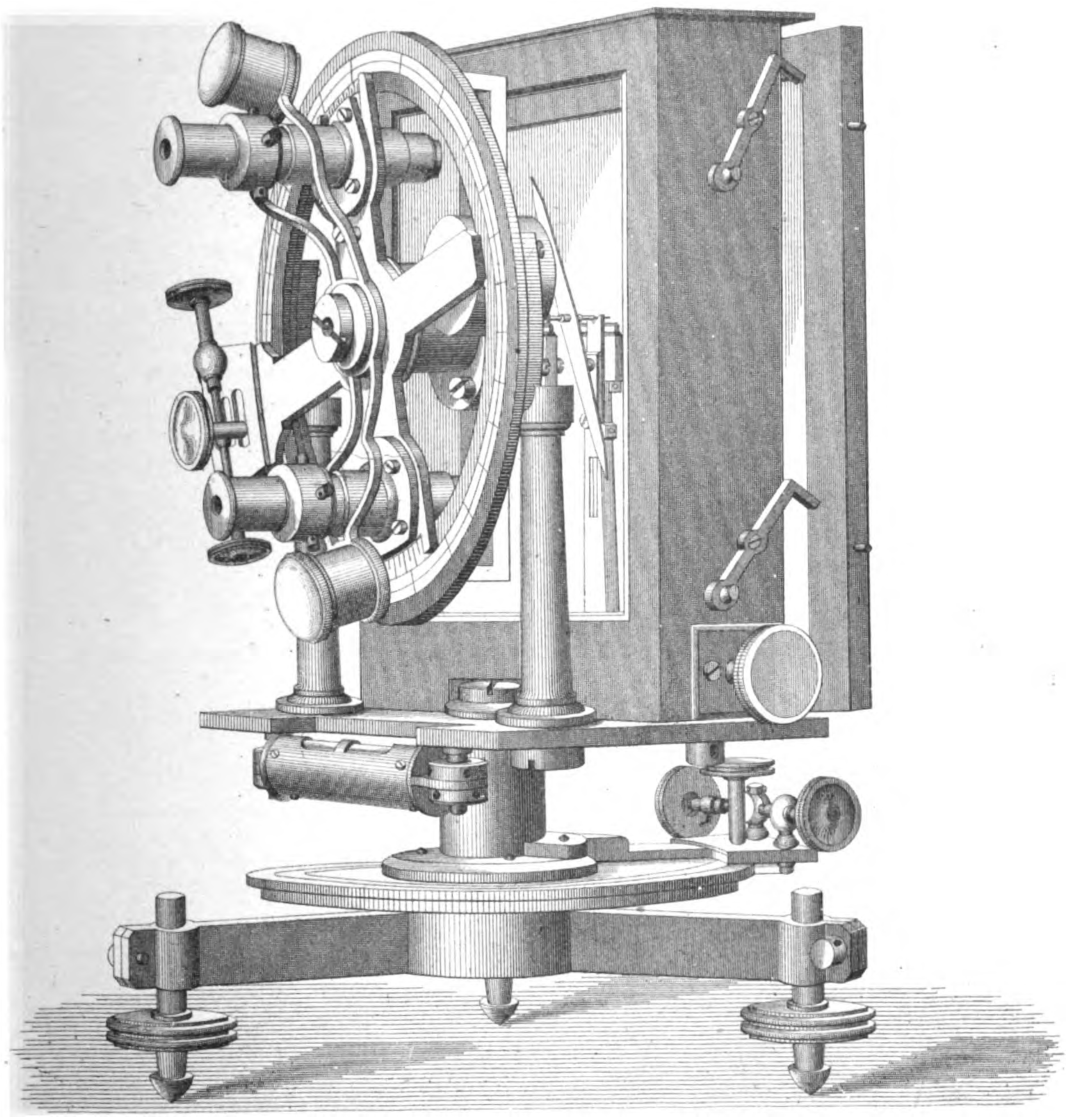
Reversal of poles of dipping-needles.—The needles which are exclusively used for the measure of the inclination should have their poles reversed at each place of observation, and the results with polarity north and polarity south must be combined to a mean value. If exceptionally the polarity should not have been reversed at a station, the difference in results between polarity north and south, as found at stations which have nearly the same dip, may be applied as a correction. To reverse the polarity, we may proceed as follows: fasten the needle in the reversing-block, and, holding a bar-magnet in each hand, bring the *opposite* poles of the two bar-magnets close together at the middle of the needle so as to touch the same on both sides of the axle; the needle is supposed to be on a level plane, and the bars are to be inclined outward about 45° to the horizon. They are then drawn slowly and steadily over the needle, carrying them *over* its ends, and, after lifting them some inches above the level of the needle, bring them back to the middle position and move them again over the surface. This process may be gone through three times, when the upper face of the needle is turned down, in which position the magnetization is repeated as before. Care should be taken to have the motion exactly in the direction of the geometrical axis of the needle; the magnetizing-block usually has a ledge, along which the magnet can be drawn, closely touching it, which will insure a movement parallel to the axis of the magnetic needle. If its north end is to be changed to a south end, place the north (or marked) end over that end of the needle when magnetizing. The polarity as well as the face may be designated by means of the number or letter usually cut on the end of the needle. The reversing-bars should be carefully handled, and should not be allowed to touch each other except at opposite poles, and when placed in the box their ends of opposite polarity should be connected by a soft-iron armature. If the reversal of the needle is to be repeated a short time after the operation, the method is only changed by using four

* See plate No. 29, illustrating this form of dip-circle.

† See plate No. 29 *bis*, illustrating the form of instrument as now made by Casella.

DIP CIRCLE





DIP CIRCLE

(KEW OBSY.)

instead of three passes over each face of the needle; if another reversal is needed shortly after, five passes would be required. This is done in order first to neutralize the existing magnetic polarity, and then to give it the opposite polarity desired; if, however, one or more days have elapsed between a reversal, enough of magnetism is lost to render any increased number of passes unnecessary. Their number depends primarily on the strength of the bars and the relative size of the bars and needles. Should the bars have too much intensity and the needles be long, an irregular distribution of magnetism might be produced. Should the bars be of unequal intensity, it is recommended to exchange them in the hands, after performing one-half of the operation of reversal, turning them at the same time end for end, and completing the operation in the new position. When not in use and when observing for dip, the bar-magnets should not be kept nearer to the observer than about ten meters; but when observing for declination they should be kept at a greater distance.

The following example of a record of ordinary observations of the dip will sufficiently show the general arrangement. The readings in the second line are independent of those of the first, and between them the needle has always been lifted off its supports. If the position of the needle is recorded while slowly oscillating, it is customary to record the left and right extreme excursions, and, in order to correct for diminution of arc, the mean of the reading of the first extreme and of its next return to it should be taken before combining with the reading of the opposite extreme. In this case, the mean for the first extreme positions may be taken mentally, and the second extreme is recorded under it; then follow two more such readings after the needle has been lifted off and let down again on the agate supports.

It is recommended to observe the needle while slowly oscillating in preference to noting its position at rest, in which case the equilibrium may be influenced by any small irregularity in the axle at the point of contact, which would be passed over by an oscillating motion. Defects in the figure of the axle may also be recognized by irregularities in the motion of the needle.

The introduction of position needles having a movable axle, which may be turned by means of a key to different positions with a view of eliminating small defects in the figure of the axle, has, so far, not proved as satisfactory as was anticipated, owing to the difficulty of perfectly figuring the axle and centering the movable arbor; if such needles are used their polarity, after the first set of observations, must be reversed, and the observations be concluded before turning to a new position.

Magnetic Dip.

Station, Washington, D. C. Date, November 10, 1853. Six-inch Barrow Dip-Circle No. 2. Needle No. 1. Observer, S. H. Time, commenced $10^h\ 15^m$ a. m.; concluded $10^h\ 33^m$ a. m.

Mean, circle E. and W., 71° 13'.3

POLARITY OF MARKED END NORTH.							
Circle east.				Circle west.			
Face east.		Face west.		Face east.		Face west.	
S.	N.	S.	N.	S.	N.	S.	N.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
71 24	71 08	71 08	71 31	71 08	70 50	70 56	70 42
26	03	08	31	00	58	54	42
71 25	71 05	71 08	71 31	71 04	70 54	70 55	70 42
71 15		71 19.5		70 59		70 48.5	
71 17.3				70 53.7			
71 05.5							

POLARITY OF MARKED END SOUTH.							
Circle west.				Circle east.			
Face west.		Face east.		Face west.		Face east.	
S.	N.	S.	N.	S.	N.	S.	N.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
71 12	71 17	71 05	71 05	71 41	71 30	71 43	71 18
11	17	04	04	45	25	44	20
71 11	71 17	71 05	71 04	71 43	71 27	71 43	71 19
71 14		71 04.5		71 35		71 31	
71 09.2				71 33.0			
71 21.1							
Resulting dip.................................... 71° 13'.3.							

Mean, circle W. and E., 71° 13'.3

NOTE.—Magnetic meridian obtained by horizontal needle, which was removed before commencing dip-observations.

Specimen of record for finding magnetic meridian.

	Azimuth-circle.
Circle south, needle south	99° 02′
Circle south, needle north	97° 58′
Circle north, needle south	278° 52′
Circle north, needle north	278° 28′
Setting: 8° 40′ and 188° 40′	98° 40′

It is desirable that in the various positions of the circle and needle the extreme readings should keep within a range of 1° or 2°; the closer the better the final result.

For the purpose of testing the regularity of the figure of the axle of the needle and the freedom of the metal of the circle from any magnetism, we may observe dips in various azimuths; if θ_a = observed dip in magnetic azimuth a, then the true inclination is found by—

$$\tan \theta = \tan \theta_a \cos a$$

The values of a may be successively changed by intervals of about 10°.

We may also obtain the true inclination, without the knowledge of the magnetic meridian, by observing the dip in any two vertical planes at right angles to each other, and find the inclination by the formula—

$$\cot^2 \theta = \cot^2 \theta_{\mathrm{I}} + \cot^2 \theta_{\mathrm{II}}$$

But the best method would seem to be that of Mayer (proposed in 1814), which is peculiarly fitted for eliminating the effect of an irregularity in the figure of the pivots, since the dip can be found on almost any part of the circumference of the axle. This method consists in loading the needle (near its axis), and thus changing its direction. The new position is conditioned by the equilibrium of the magnetic force and that of gravity. The tilt may amount to 90° or more; and should the needle be deflected into the adjacent quadrant, the algebraic sign of the observed dip changes, and must be attended to. For want of a better contrivance, a drop of sealing-wax may be applied to the side of the needle near its axle, and observations may be made with the needle variously deflected by changing its quantity, or by letting it act at a different leverage. The ordinary rules for observing dip are adhered to, but special care must be taken that the weight be not changed in position in the act of reversing the polarity. This method of reduction may also be followed if ordinary needles differ as much as 3° or 4° in any of their separate results, due to change of face or polarity.

Let θ_{I}, θ_{II}, θ_{III}, θ_{IIII}, be the observed dips, say, with face of needle E, face W, and after change of polarity, with face W and face E, respectively, and—

$$\mathrm{M} = \cot \theta_{\mathrm{I}} + \cot \theta_{\mathrm{II}} \qquad \mathrm{N} = \cot \theta_{\mathrm{III}} + \cot \theta_{\mathrm{IIII}}$$
$$m = \cot \theta_{\mathrm{I}} - \cot \theta_{\mathrm{II}} \qquad n = \cot \theta_{\mathrm{III}} - \cot \theta_{\mathrm{IIII}}$$

Then—

$$\cot \theta = \frac{\mathrm{M}\,n + \mathrm{N}\,m}{2\,(m + n)}$$

The record, as given in the following example to this method, shows that the dip was noted while the needle was oscillating, and that between the second and third horizontal lines the needle was lifted off the agates and let down again.

Magnetic Dip.

Station, Washington, D. C. Date, September 22, 1856. Dip-Circle Barrow No. 5. Needle No. 2, loaded near axle. Observer, C. A. S. Time, commenced $11^h\ 30^m$; concluded $11^h\ 55^m$.

POLARITY OF MARKED END NORTH.							
Circle east.				Circle west.			
Face east.		Face west.		Face east.		Face west.	
S.	N.	S.	N.	S.	N.	S.	N.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
−34 50	−34 50	24 10	24 38	−35 30	−34 02	25 12	25 12
−35 25	−35 18	24 48	24 00	−34 10	−35 18	24 42	24 40
−34 45	−35 09	24 46	24 35	−33 59	−33 49	25 20	24 32
−35 38	−35 00	24 15	24 05	−35 38	−35 22	24 35	25 12
−35 09.5	−35 04.2	24 30.0	24 19.5	−34 49.2	−34 37.8	24 57.2	24 54.0
−35 06.9		24 24.7		−34 43.5		24 55.6	
−34 43.5		24 55.6					
θ_{I} = −34 55.2		θ_{II} = 24 40.2					

POLARITY OF MARKED END SOUTH.							
Circle west.				Circle east.			
Face west.		Face east.		Face west.		Face east.	
S.	N.	S.	N.	S.	N.	S.	N.
° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
−41 00	−41 55	29 30	29 27	−42 14	−41 03	29 55	29 09
−42 10	−40 48	30 30	30 23	−41 02	−42 08	29 20	29 41
−42 10	−40 50	30 35	30 29	−42 09	−42 05	29 29	29 18
−41 00	−41 51	29 25	29 20	−41 10	−41 10	29 48	29 35
−41 35	−41 1	30 00	29 54.8	−41 38.8	−41 36.5	29 38.0	29 25.8
−41 28.0		29 57.4		−41 37.7		29 31	
−41 37.7		29 31.9					
θ_{III} = −41 32.8		θ_{IIII} = 29 44.6					

Azimuth-circle.

Magnetic prime vertical .... 69° 00′ by north polarity.
Magnetic prime vertical .... 247° 50′ by south polarity.

Mean .... 68° 25′

Determined before needle was loaded.

Computation.

M .... $= +0.74476$
m .... $= -3.60956$
N .... $= +0.62167$
n .... $= -2.87855$

$\therefore\ \theta$ .... $= +71°\ 19'.1$

3. ABSOLUTE AND RELATIVE MEASURES OF THE MAGNETIC FORCE.

It is usual, when accurate results are desired, to measure the horizontal component of the magnetic force by means of a portable magnetometer, and the dip by means of a dip-circle, and to derive the total force by combining these. In high magnetic latitudes, where the horizontal component is feeble in comparison with the vertical component, Lloyd's statical method is to be preferred. To measure the horizontal force, two distinct operations are required, known as "Observations of Deflections" and "Observations of Oscillations." Their combination will enable us to separate, in the observed force, that part which is due to the magnetism of the magnet from that which is due to the earth's magnetism. Either of these operations, but especially the latter, will determine relative horizontal intensity, and, when used in connection with a base-station where the magnetic force is known, absolute results will also be obtained. In this case the observer should return to the base-station after the completion of his magnetic survey, and again measure the magnetism of his magnet, which, in the interval, must be carefully guarded against changes, and the results must be corrected, if necessary, for loss of magnetism.

The magnetometer.—There are two forms of unifilar magnetometers in use: those with a complete astronomical theodolite, or alt-azimuth, mounted to the magnetic north or south of the box in which the collimator-magnet is suspended, and on the *same* stand with it; and those which have the box with suspended magnet mounted centrally over, and firmly connected with, an azimuth-circle, the reading-telescope being mounted eccentrically on supports. The first form (supposed to have been devised by Gauss) is the preferable one in field use; it admits of greater expedition, allows of greater ease in observing, and is almost indispensable when the astronomical meridian has to be determined. With the magnet to the south of the theodolite, it readily admits of observations of the sun, for the determination of time and azimuth (also of latitude, if required) without interfering with the magnetic work proper. Deflections are read off on the scale of the collimator-magnet, and must be converted into angular measures. The second form* (supposed to have been given by Dr. Lamont) is capable, perhaps, of greater accuracy, and is better suited for a fixed observatory, especially when declination disturbances also are to be observed, or at stations where there is a large daily range in the declination. The angles of deflection are at once read off. In order to observe the azimuth-mark, the magnet and box have temporarily to be removed, which is unnecessary in the first form of the instrument. When observing deflections, the bar, and consequently the deflecting magnet, remain fixed in the magnetic prime vertical, in the magnetometer, with attached theodolite; but in the second form of the instrument the deflecting and deflected magnets always remain at right angles to each other.† Improvements have been made at the Coast Survey Office in the construction of magnetometers, with a special view of making them more portable than the older instruments, which were found unnecessarily large and heavy. In 1871, a three-inch Casella theodolite was utilized for this purpose. The magnet (3 inches long and ¼ inch in diameter) and light box, with glass tube, were first attached to the upper frame of the theodolite; afterward to its stand, by which greater steadiness was secured. The relative horizontal intensity only could be measured by means of oscillations. In October, 1874, a similar instrument was fitted up with 2 magnets, inertia-ring, and deflecting bar for absolute measure, the magnets being only about 1⅓ and 1½ inches in length. In the present year several instruments were constructed with 4-inch theodolites and magnets, 1.50 and 1.84 inches in length, respectively; diameter, 0.3 inch. One of these instruments is presented in the accompanying plate. The upper part of the theodolite can be removed and the magnet-box placed on its azimuth-circle. The operation for either construction of the instrument is essentially the same, and the simple modifications necessary in using one or the other form in observing and computing will be specially noted under the appropriate heads of the work. When observing for time and for duration of oscillations, a mean-time box-chronometer is most convenient for use; the observer will himself take up the beat (half-second) and estimate fractions of seconds. For a traveler, who dislikes to be much incumbered, a pocket-chronometer is much to be preferred, but the counting of the beats, generally five in two

* See plates containing representations of magnetometers, No. 27 of a large-sized and No. 28 of a small-sized instrument.

† In this case, the bar and box turning on the center of the azimuth-circle, a measurable amount of induced magnetism is developed in the deflector when inclined to the magnetic prime vertical.

seconds, requires some previous practice. It is recommended to take up an even beat—say at 0, 10, 20, 30, &c., seconds—and count only the even beats, repeating the letters *a b c d* in the intervals; thus, 10 *a b c d*, 12 *a b c d*, 14 *a*, &c. The letters are afterward converted into their equivalents of time; thus, 14 *c* would be $15^s.2$.

Observations of deflections.—The instrument being adjusted as for observations of declination, attach the deflecting bar, suspend the shorter of the two magnets generally supplied for each instrument; the line of detorsion having been placed in the magnetic meridian, insert the copper damper, raise the suspended magnet to the horizontal level of the deflecting (or long) magnet, put the carrier at the proper distance on the bar, and, after placing the intensity (or long) magnet* centrally on it, commence making the observations as indicated in the following scheme:

HORIZONTAL INTENSITY. DEFLECTIONS.

FORM 1.

Magnetometer with attached theodolite. Deflecting magnet in the magnetic prime vertical.

Station, Hampton. Date, July 11, 1862. Magnet C_{32} deflecting. Magnet S_8 suspended. Observer, N. N.

Magnet.	North end.	Time.		Temperature. t.	Scale-readings.	Alternate means.	Differences.	Distance.
		h.	m.	°				
West.	W.	10	22	78.8	20.2			$r = 2$ feet; $\log r = 0.30103$
	E.				133.5	20.30	113.20	
	W.		33	79.0	20.4	133.55	.15	
	E.				133.6			
		10	27.5	78.9			113.18	
East.	E.	10	26	79.0	133.0			
	W.				20.0	133.05	113.05	
	E.	10	29	79.0	133.1	19.95	.15	
	W.				19.9			
		10	27.5	79.0			113.10	
Means		10	27.5	79.0		$2u$	113.14	

Torsion-circle.	Scale.	Differences.			Logarithms.
°					
83	76.5	2.7	$u =$	$56^d.57$	1.75259
173	79.2	5.6	$1^d =$	$2'.843$	0.45378
353	73.6	2.9	$1+\frac{h}{f}$		0.00064
83	76.5				
$\frac{1}{4}\Sigma$ or mean $= v = 2.80$			$u =$	$161'.07$	2.20701
				$= 2^\circ\ 41'.07$	
	Logarithms.			Tan u	8.67106
				r^3	0.90309
$v = 7'.96$				$\frac{1}{2}$	9.69897
$5400' + v'$	3.73303			$1 - \frac{P}{r^2}$	0.00040
5400 (ar. co.)	6.26761				
$1+\frac{h}{f}$	0.00064			$\frac{m}{H}$	9.27352

NOTE.—The order of time indicated above is designed to correct for changes in declination during the observations of deflections.

*A vertical plane passing through its axis should also pass through the line of suspension of the shorter magnet.

HORIZONTAL INTENSITY. DEFLECTIONS.

FORM 2.

Theodolite magnetometer. Deflecting and deflected magnets at right angles to each other.

Station, Washington, D. C. Date, May 16, 1867. Magnet A deflecting. Magnet B suspended.
Distance, $r=1\frac{1}{6}$ feet. Log r=0.06695. Observer, C. A. S.

Magnet.	North end.	Circle-readings. No.	A	B	Mean.	Circle-readings. No.	A	B	Mean.
			° ′	′	′		° ′	′	′
East.	E.	1	250 40.5	40.5	40.50				
	W.					2	237 29.5	29.0	29.25
	E.	3	40.5	40.0	40.25				
	W.					4	29.0	28.5	28.75
	E.	5	42.0	42.0	42.00				
	Mean				40.92				29.00
West.	W.					6	237 32.5	32.0	32.25
	E.	7	250 32.0	31.5	31.75				
	W.					8	32.5	32.5	32.50
	E.	9	31.0	31.0	31.00				
	W.					10	33.0	32.5	32.75
	Mean				31.37				32.50

		Logs.
° ′		
Magnet E., $2u$ = 13 11.92	$\frac{1}{2}$	9.69897
Magnet W., $2u$ = 12 58.87	r^3	0.20085
Mean = 13 05.40	Sin u	9.05684
u = 6 32.70	$1-\frac{P}{r^2}$	0.00136
h. m. °		
Time of commencing, 3 29 Temp., 63.5 Fah.	Induction*	0.00009
Time of ending, 3 45 Temp., 65.8 Fah.		
64.65	$\frac{m}{H}$	8.95811

The preceding forms are arranged for determining the angle of deflection (u) by which the intensity-magnet, acting at a given distance, r (expressed in feet), deflects the suspended magnet from the magnetic meridian, and for determining the ratio of the magnetic force (m) of the deflecting magnet to that of the earth's horizontal component (H). For the case of the deflector remaining in the magnetic prime vertical, we have, with sufficient precision—

$$\frac{m}{H}=\frac{1}{2}r^3\tan u\left(1-\frac{P}{r^2}-\frac{Q}{r^4}\quad . \quad . \quad . \right)$$

for the case of the magnets remaining at right angles—

$$\frac{m}{H}=\frac{1}{2}r^3\sin u\left(1-\frac{P}{r^2}-\frac{Q}{r^4}\quad . \quad . \quad . \right)$$

where the terms $\frac{Q}{r^4}$, etc., may be omitted as too small to affect sensibly ordinary observations.

The first form requires the torsion of the suspension to be measured and to be corrected for; in the second form, no twist is developed. The co-efficient P, depending upon the distribution of magnetism within the deflecting magnet, must be ascertained experimentally by means of deflections at two or three distances, and at least twenty-five independent measures should be made for its numerical value; it will generally be found to have a negative sign, provided the magnets have their proper proportions of length, viz: short magnet to long magnet, as 1 to 1.224.

* For method of determining the effect of induction and example of its application, see Coast Survey Report of 1869, Appendix No. 9.

To find P, let A = value of $\frac{m}{H}$ for the shorter distance r, and A_1 = value of $\frac{m}{H}$ for the longer distance r_1; then—

$$P = \frac{A - A_1}{\frac{A}{r^2} - \frac{A^1}{r_1^2}}$$

If for any two consecutive sets of observations the temperature of the intensity-magnet is not the same, a correction for difference of temperature has first to be applied* to the observed angle of deflection. It may be done by means of the expression—

$$\sin u = \frac{\sin u_0}{1 - (t_0 - t)\, q}$$

where u_0 = observed angle of deflection of first set at temperature t_0;

u = corrected angle in order to refer it to the standard temperature t of the second set;

q = temperature co-efficient, to be determined from a series of observations of deflections, at a fixed distance, but at various temperatures.

The co-efficient Q, depending on the fourth power of r, may be neglected. The two distances r and r_1 (to be measured from the middle of the magnets) may be in the ratio of 1 to $\sqrt{2}$ nearly, but not to exceed 1 to $\sqrt{3}$; or, for convenience, the second distance may be one-half greater than the first, but the shorter distance should not be less than about four times the length of the deflecting magnet. The correction for induction in Form 2 may be neglected in all cases where extreme accuracy is not required. In observing with the magnetometer and attached theodolite, we may save time by noting the two extreme scale-readings of an oscillation, instead of waiting for the magnet to come to rest; and, in Form 2, we can also reduce the time of observation by setting the azimuth-circle beforehand nearly to the reading corresponding to the particular position of the magnet, and afterward perfecting the pointing on the middle division by the azimuth-screw. The scale of the deflecting bar† should be examined for graduation and eccentricity errors, and corrected for them if necessary. When using a magnetometer with theodolite, the angular value of the scale of the deflected magnet must be ascertained with great precision, and, in general, special attention is to be paid to the temperature of the intensity-magnet, which must be the same, or be reduced to the same, temperature during the observations of deflections and oscillations. These two operations should, therefore, always immediately follow each other.

Observations of oscillations.—The instrument being adjusted, and the intensity (long) magnet‡ suspended without twist, with scale horizontal, and the copper damper removed, the observer will arrange his scheme for observing the duration of a certain number of oscillations, from which the time of one oscillation is to be deduced. The bulb of the thermometer to indicate the temperature of the magnet is put inside the box, the stem projecting outside. The mean-time chronometer,§ whose rate must be known, is placed at a safe distance below the telescope, allowing, however, the observer to take up the time without changing his place.

With the magnet at rest, the vertical thread of the telescope should point nearly to the reading on the scale of the magnetic axis, or to the center division. Care must be taken that the magnet have no up and down vibrations; a horizontal motion is then given to it by means of a small magnetized piece of steel, sufficient to make it oscillate for about twenty or twenty-five minutes before coming to rest. The oscillations are counted as follows: Suppose the center division of the scale to pass from apparent right to left, call its first transit over the line of collimation of the telescope 0, and note the time (the minute having previously been noted, the second is added without taking the eye off the telescope); its next transit will be from left to right and is called 1, the next following one from right to left is called 2, and so on until the tenth transit is observed, when the time

* For greater accuracy, the values of A and A_1 require also to be corrected for effect of induction in that form of instruments giving the *deflection-angle* directly. See "On Induction," Coast Survey Report of 1869, Appendix No. 9.

† A wooden bar is preferable to one of brass, on account of its greater lightness and less variability in length with change of temperature.

‡ This magnet generally serves also for observations of declination.

§ If sidereal, we simply consider it as a mean-time chronometer with a large rate, and correct for it accordingly.

is again noted, for which purpose the beat of the chronometer has to be taken up in the usual manner. The duration of ten oscillations being thus approximately known, the intervals and whole number of oscillations to be observed can be properly arranged. With the light magnets now in use, two fibers, and for those used in connection with three-inch Casella theodolites, even a single fiber suffices for the suspension. The best arrangement yet devised for ordinarily observing oscillations is the following: Begin with apparent motion of the magnet, say, from right to left, and note the times of, say, three transits; then take an equal number from left to right, to be followed, after an interval of a few minutes (of rest to the observer), in order to get the duration for, say, one hundred oscillations, by a similar set of transits from right to left; and conclude finally with an equal number of transits from left to right. It will be noticed that for even numbers of oscillations the apparent motion is from right to left, for odd numbers the reverse. We thus provide experimentally for any effect of a change in the declination during the observations, the final mean duration of one oscillation being unaffected by any such change. It is advisable not to extend the entire time consumed in a set of observations beyond a quarter of an hour, and to make the interval between any two consecutive observations (the magnet swinging in the same direction) between one-third and two-thirds of a minute. This gives ample time to take up the beat of the chronometer, which is done, say, ten seconds before the expected time of transit, and to await it deliberately. The arrangement for a particular case is shown in the form given below; here the three intervals (rough ones only) of 39^s, 43^s, and $3^m\ 12^s$ are known beforehand, and must be mentally added to the observed time in order to be prepared for the next following transits. With the time of a transit only roughly known, the observer will not be biased in his estimation of the observed fraction of a second. For each particular magnet, depending mainly on its mass and magnetic intensity, a special scheme must be devised, guided by the principles as explained above; but the same scheme may be adhered to for a number of stations, unless the survey extends over a space within the limits of which the earth's horizontal force has widely different values. Special attention is to be paid to the correct noting of the temperature, and the observations must be accompanied by measures of the torsion. The correction for induction may be omitted except when great accuracy is demanded; it arises from the fact of the magnet having greater force, by induction, when suspended in the magnetic meridian, than in the position at right angles to it (as in deflections). On the subject of induction, see Coast Survey Report of 1869, Appendix No. 9.

HORIZONTAL INTENSITY. OSCILLATIONS.

Station, Washington, D. C. Date, August 12, 1871. Magnet A suspended. Inertia-ring, No. — (not used). Chronometer, Park. & Frod., 1216. Daily rate, $-1^s.75$ on mean time. Observer, C. A. S.

No. of oscillations.	Time.	Temperature. t'	Extreme scale-readings.		Time of 100 oscillations.
	h. m. s.	°			m. s.
0	11 28 24.0	79.0 Fah.	0.0	18.8	
10	29 03.0				
20	42.2				
31	30 25.1				
41	31 04.2				
51	43.2				
		79.5	1.8	16.8	
100	34 55.2				6 31.2
110	35 34.3				31.3
120	36 13.5				31.3
131	56.2				31.1
141	37 35.3				31.1
151	38 14.2	80.0	4.0	14.8	31.0
Means..........		79.5	....	....	6 31.17

Co-efficient of torsion. Value of one scale-division = 2'.90.

Torsion circle.	Scale.		Mean.	Differences.	$v = 2'.75$	Logarithms.
°						
300	8.8	11.2	10.0			
				1.0	$5400' + v'$	3.73261
30	7.5	10.5	9.0			
				1.9	5400 (ar. co.)	6.26761
210	9.8	12.0	10.9			
				0.9		
300	9.2	10.8	10.0			
					$1+\frac{h}{f}$	0.00022
	$\frac{1}{3}\Sigma$ or mean $= v =$			0.95		

Calculation by—

$$T^2 = T'^2\left(1+\frac{h}{f}\right)\left(1-(t'-t)\,q\right)$$

		s.
Observed time of 100 oscillations	=	391.17
Time of one oscillation	=	3.9117
Correction for rate	= −	0.0001
T'	=	3.9116

			Logarithms.
q	0.00027	T'	0.59235
$t'-t$	$+$ 0.33		
$(t'-t)\,q$	0.00009	T'^2	1.18470
		$1+\frac{h}{f}$	0.00022
$1-(t'-t)\,q$	0.99991	$1-(t'-t)\,q$	9.99996
		Induction	0.00079
	$m\,H = \frac{\pi^2 K}{T^2}$	T^2	1.18567
		$\pi^2 K$	1.40062
		$m\,H$	0.21495
		m	9.57516
		$4.3630 = H$	0.63979
		$*\frac{m}{H}$	8.93537
		$m\,H$	0.21495
		m^2	9.15032
		$0.3760 = m$	9.57516

* From observations of deflection: Date, August 12; $t = 79^\circ.17$ Fah.

Let H = the horizontal component of the earth's magnetic force; m = the magnetic moment of the intensity-magnet; K = its moment of inertia (inclusive of stirrup and balancing-ring,† if any); T = the time of one oscillation: then, from observations of oscillations, we have the expression for the product—

$$m\,H = \frac{\pi^2 K}{T^2}$$

where $\pi = 3.14159$

The observations of deflections give the ratio $\frac{m}{H}$ and the observations of oscillations the product m H; m and H can therefore be eliminated from the two equations, as shown in the preceding example.

To determine K, a truly-turned brass or bronze ring of known dimensions and weight (about equal to that of the magnet) is placed on the magnet. It is correctly centered by means of two centering-blocks, and when suspended must remain in a horizontal plane. The number of suspension-fibers must be doubled for the purpose. In this position a set of oscillations is observed similar in arrangement to that already explained; and if T_1 be the time of one oscillation of the loaded magnet, and K_1 the moment of inertia of the ring, then—

$$K = K_1 \left(\frac{T^2}{T_1^2 - T^2}\right)$$

A series of not less than twelve sets of observations of oscillations, with the magnet *alternately* unloaded and loaded, is to be made, each set duly corrected for torsion, rate of chronometer, and difference of temperature, from which the value of K is deduced. These results are to be combined with a view of eliminating the effect of changes in H during the observations; thus the mean of sets 1 and 3 is used with set 2, the mean of 3 and 5 with 4, &c., the first and last sets being alike either with magnet unloaded or loaded. As the torsion changes with the weight, observations for torsion must also be made with the loaded magnet. To find K_1 let r and r_1 represent the inner and outer radii, expressed in decimals of a foot, and w the weight of the ring in grains, then—

$$K_1 = \tfrac{1}{2}\,(r^2 + r_1^2)\,w$$

The values of log π^2 K for different temperatures should be tabulated. It suffices to assume the ordinary co-efficient of expansion for brass (0.000010).

† This small balancing-ring must remain in the same position as in the observations for intensity; but its use should be avoided, if at all possible.

The reduction of the time of an oscillation to an infinitesimal arc is generally so small as not to affect the magnetic results. If a and a' express the initial and terminal semi-arcs of an oscillation (in parts of the radius), then the corrected value for T^2 will be—

$$\left(1 - \frac{a\,a'}{16}\right)^2 T^2$$

This correction can be avoided by swinging only through small arcs.

To reduce the measures of deflections and oscillations to the same temperature, let $t =$ the temperature of the magnet when deflecting; $t_1 =$ its temperature when oscillating; $q =$ the change in magnetic moment of magnet for a change in temperature of 1° Fahrenheit, then the co-efficient to be applied to T^2 is equal to $1 - (t' - t)\,q$, as shown in the example. The value of q is not constant, but, for a moderate range of temperature, may be taken as constant; it must be obtained experimentally, either from oscillations or from deflections, at various temperatures, but the magnet should not be subjected to a greater range of temperature than from about 32° to 100° Fahrenheit. These observations must be conducted by the alternate use of a jacket of ice and of hot water, or by the aid of extreme natural temperatures; ample time must, however, be given to the magnet to establish again an equilibrium in its magnetism; all *rapid* changes from cold to hot (or *vice versa*), will give decidedly erroneous values for q.

Supposing not less that three consecutive series of observations of deflections for finding a value of q, and the first and third series to be at nearly the same temperature, with their results combined to a mean, and the second or intermediate series at a greatly different temperature, then q may be found, with sufficient precision, by the expression—

$$q = \frac{a\,n \cot u}{t - t_0}$$

where $a =$ the arc value of one division of the scale of the suspended magnet in terms of the radius; $n =$ the difference of scale-readings corresponding to the difference of temperature $t - t_0$; and $u =$ angle of deflection at the lower temperature t_0. In every case the arrangement must be such as to eliminate, as far as possible, any effects of changes in declination and intensity during the observations. If other instruments are available, it is best to correct the readings for observed changes in declination and intensity.

Example to observations of deflections for value of q of magnet H.

Washington, D. C. Magnetic observatory. J. S. H., observer. April 14, 1856. Magnet C_{17} suspended. Magnet H deflecting at a distance of 21 inches to the east of suspended magnet Mean declination-reading of the day, $62^d.4$. One scale-division of $C_{17} = 2'.80$.

Time.	Number of sets.	Declination-reading.*	Scale-reading of C_{17}, mean of five observations.	Mean minus observed declination.	Correction for change in declination.	Reading of C_{17} corrected.	Observed temperature, Fahrenheit.
h. m.		*d.*	*d.*	*d.*	*d.*	*d.*	°
10 02 a. m.	1	59.3	28.82	+3.1	−1.11	27.71	44.0
	2	59.9	28.84	2.5	0.89	27.95	57.3
	3	60.5	29.07	1.9	0.67	28.40	73.1
	4	60.9	29.15	1.5	0.54	28.61	87.9
	5	61.3	28.73	1.1	0.39	28.34	74.3
	5	61.8	28.21	0.6	0.22	27.99	57.3
	7	62.2	27.64	0.2	0.07	27.57	42.8
	etc.						

* Brooke's declinometer; 1 division of scale = 1'.

		d.
Reading of C_{17} before introducing H		149.4
Reading of C_{17} during deflection		28.0
Reading of C_{17} after removing H		149.3
Angle of deflection	5° 39'.6 =	121.3

The above partial results, which form but a portion of the observations taken, may be arranged as follows:

Set number—	Mean temperature.	Mean reading of C_{17}.	Differences in— Temperature.	Scale-divisions.
	°	d.	°	d.
1 and 7....	43.4	27.64	22.2	0.51
2 and 6....	57.3	27.97	8.3	0.18
3 and 5....	73.7	28.37	8.1	0.22
4.........	87.9	28.61	22.3	0.46
Mean..	65.6	28.15	Sum, 60.9	1.37

Log a	0.447
Co. log rad. in minutes	6.464
Log n	0.137
Log cot u	1.004
Co. log $(t - t_0)$	8.215
Log q	6.267

$q = 0.000185$

If it is desirable to check the preceding result, we can also find the value of q from three or more consecutive series of oscillations (always combined in accordance with the principle of eliminating changes in intensity) at different temperatures. Let T and T_0 be the observed times of one oscillation (corrected for rate of chronometer and effect of dilatation of magnet) at the temperatures t and t_0, then—

$$q = \frac{T^2 - T_0^2}{T_0^2\,(t - t_0)}$$

If the magnetic moment m of the magnet has been determined at a number of stations, the different values may be reduced to a standard temperature. Let m_0 = magnetic moment at the standard temperature t_0; m = the magnetic moment at any other temperature t, then—

$$m_0 = m\,[1 + (t - t_0)\,q]$$

If the values of m_0 are arranged according to time, the gradual loss of magnetism will become apparent in a few weeks, unless the magnet be an old one, when yearly determinations of m indicate but a slight loss. A new magnet is not well suited for intensity-determinations until the lapse of a month or two. See Coast Survey Report of 1857, Appendix No. 32.

If F = total magnetic force; H = its horizontal component; V = its vertical component; and θ = the angle of the dip (reckoned from a horizontal line), then—

$$F = H \sec \theta = V \operatorname{cosec} \theta$$

To convert measures of intensity expressed in British units into their equivalents expressed in the metric system, in which the millimeter = 0.00328087 foot and the milligram = 0.0154323 grain are adopted, we multiply by the factor 0.46108 (log factor = 9.66378). Its reciprocal is 2.1688 (log reciprocal factor = 0.33622), by which intensity-measures expressed in metric units are to be multiplied to give their equivalents, according to the British weights and measures.*

* The units for the measure of the earth's magnetic force are the second of mean time, the foot (or, in the metric system, the millimetre) and the grain (or, in the metric system, the milligram). In statical measure the unit of magnetic force is the pressure of a unit mass under the influence of a unit force, which would produce, if the mass be free, during one second a velocity of one unit, and not a velocity g (which in latitude 45° is equal to 32.17 feet, or $9^m.806$), as is commonly adopted in works on dynamics. This adopted unit of measure, considered dynamically, implies that the unit of accelerative force will produce the velocity 1 in the time 1. This unit of force is therefore g times smaller than the unit of gravitation-force. Thus, supposing the horizontal force of the earth's magnetism to be (in British units) 4.35 at

CONCLUDING REMARKS.—The degree of accuracy attainable in the magnetic measures can only be estimated, chiefly on account of the almost incessant changes in the action of terrestrial magnetism. With well-constructed instruments, such as have been supposed in this article, and with fair observations, the resulting declination for any one day may, in our magnetic latitudes, be affected with no greater probable uncertainty than about $\pm 1'$ to $\pm 3'$, and correspondingly less if the observations extend over more than one day. The dip may be affected with a probable uncertainty between $\pm 1'$ and $\pm 5'$, according to the perfection of the needles and the number of observations made; and the horizontal intensity, in general, may become known within about its $\frac{1}{400}$ part from any one day's observations. To find the effect on the total force, we have the relation—

$$d\,F = d\,H \sec\theta + F \tan\theta\, d\,\theta$$

To secure uniformity and completeness of record, the Coast Survey observers are furnished with blank forms, Nos. 1 to 5.*

Washington in 1877, what is meant is that this force is equal to a pressure of a mass of 4.35 grains when under the influence of an attractive force which would produce during one second a velocity of one foot. The same, if expressed in ordinary units of gravitation-force, would be $\frac{4.35}{32.17}$, or 0.135 grain of pressure under the earth's attraction.

The unit of magnetic force in the metric system is $\frac{1}{9806}$ of that of gravity; hence the unit of magnetic force in the British system is to that of the metric system as 9806 : 32.17, or nearly 305 times greater than the latter. To change numerical measures of intensity expressed in units of the metric system into their equivalents expressed in C. G. S. measure (or in units of the centimetre, the gramme, and the second), we have only to shift the decimal point one place to the left.

The earth's magnetic energy acts upon a magnet as a couple, the attractive force exerted on one-half of the magnet being equal and opposite in direction to the repulsive force on the other half.

* For further information on the subject of this paper the reader may consult the following works:

Magnetical Instructions for the use of portable instruments, etc., etc., by Lieut. C. J. B. Riddell, R. A., F. R. S., London, 1844; with supplement, London, 1846.

Handbuch des Erdmagnetismus, Dr. J. Lamont. Berlin, 1849.

Manual of Terrestrial Magnetism, by Major-General Sir E. Sabine. Extracted from the Admiralty's Manual of Scientific Enquiry, third edition, 1859.

Terrestrial and Cosmical Magnetism. The Adams Prize Essay for 1865, by E. Walker, M. A. Cambridge (England), 1866.

A treatise on magnetism, by Sir G. B. Airy. London, 1870.

A treatise on magnetism, general and terrestrial, by H. Lloyd, D. D., D. C. L. London, 1874.

APPENDIX No. 17.

METHOD OF CLOSING A CIRCUIT OF TRIANGULATION UNDER CERTAIN GIVEN CONDITIONS, BY CHARLES A. SCHOTT, ASSISTANT, AND M. H. DOOLITTLE, UNITED STATES COAST SURVEY.

It has been deemed desirable to preface this paper by some general and explanatory remarks on the adjustment of triangulations by application of the method of least squares.

First, with respect to directions or angles measured at any station. Such measures will exhibit small discrepancies, which are caused by the unavoidable imperfections of measure. They are indicated by the want of identity in the value of any angular space resulting from the difference of its two directions when deduced in more than one way from different combinations or series of measures.* If angles are measured directly by means of repeating-instruments (now only used in subordinate triangulations), we find discrepancies in the sum of two or more angles given separately when compared with the whole space measured.† To this kind of conditions also belongs that of

* For method of treatment and example, see Coast Survey Report for 1854, Appendix No. 33, pp. 71 to 76, Art. A; and for the determination of the probable error of a resulting direction, Coast Survey Report for 1864, Appendix No. 14, pp. 120 to 124, Art. 3.

† For treatment and example, see Report for 1854, Appendix No. 33, pp. 76 to 79, Art. B; and the briefer method with the aid of correlations, in the Report for 1868, Appendix No. 8, pp. 141, 142. The probable error of each angle is deduced in the usual way; but, as triangulations are now generally adjusted "by directions" and not "by angles," we require to know the probable error and weight of each direction. The process given in the Report for 1864, pp. 124, 125, Art. 4, has been superseded, since 1868, by the simpler one of treating an angle as the difference of two directions; and since no example has yet been given, the following one will suffice to indicate the process.

Suppose but two angles measured, and each individual measure to consist of an equal number of *repetitions*, we subtract the mean (or resulting angle from adjustment, as the case may be) from each measure, and arrange as fol lows:

STATION, BURDEN.

Abstract of remaining errors. *Errors and their squares.*

[N. B.—To avoid the negative sign, we subtract from 60″.]

Pine Mt.	Deakyne.	Buck.	Mean.		Pine Mt. Δ	Pine Mt. Δ²	Deakyne. Δ	Deakyne. Δ²	Buck. Δ	Buck. Δ²
	″	″	″							
0	59.2	....	59.6		0.4	0.2	0.4	0.2	......	......
0	59.6	....	59.8		0.2	0.0	0.2	0.0	......	......
0	56.0	....	58.0		2.0	4.0	2.0	4.0	......	......
0	59.7	....	59.9		0.1	0.0	0.2	0.0	......	......
0	2.4	....	1.2		1.2	1.4	1.2	1.4	......	......
0	59.4	....	59.7		0.3	0.1	0.3	0.1	......	......
0	59.7	....	59.8		0.2	0.0	0.1	0.0	......	......
0	59.5	....	59.8		0.2	0.0	0.3	0.1	......	......
0	0.7	....	0.3		0.3	0.1	0.4	0.2	......	......
0	2.5	....	1.2		1.2	1.4	1.3	1.7	......	......
0	0.8	....	0.4		0.4	0.2	0.4	0.2	......	......
0	1.2	....	0.6		0.6	0.4	0.6	0.4	......	......
0	59.4	....	59.7		0.3	0.1	0.3	0.1	......	......
0	59.7	....	59.9		0.1	0.0	0.2	0.0	......	......
....	0	0.9	0.4		......	......	0.4	0.2	0.5	0.2
....	0	3.5	1.7		......	......	1.7	2.9	1.8	3.2
....	0	0.6	0.3		......	......	0.3	0.1	0.3	0.1
....	0	1.3	0.6		......	......	0.6	0.4	0.7	0.5
....	0	0.6	0.3		......	......	0.3	0.1	0.3	0.1
....	0	58.2	59.1		......	......	0.9	0.8	0.9	0.8
....	0	58.0	59.0		......	......	1.0	1.0	1.0	1.0
....	0	0.3	0.1		......	......	0.1	0.0	0.2	0.0
....	0	58.2	59.1		......	......	0.9	0.8	0.9	0.8
....	0	56.7	58.3		......	......	1.7	2.9	1.6	2.6
....	0	0.8	0.4		......	......	0.4	0.2	0.4	0.2
....	0	0.8	0.4		......	......	0.4	0.2	0.4	0.2
				Σ=	.....	7.9	.....	18.0	.....	9.7

closing the horizon, or the requirement that the whole measured angular space around the station equal 360°. Existing conditions of this kind, either among directions or angles at a station, may be termed "local conditions;" and the equations established for dispersing the errors may be termed "local equations."

A second source of discrepancies is found in the fact that certain geometrical conditions existing in the figure of the triangulation remain unsatisfied. Thus, the sum of the angles in each triangle must equal two right angles plus the spherical excess. Also, all directions *intended* to radiate from or to converge to certain stations must really do so. The former conditions give rise to what have been called angle equations; the latter, to side equations. If both kinds of conditions are satisfied we shall find the same length and direction for any side, no matter through what series of triangles it may be computed. These equations are, in a measure, exchangeable; thus, in the adjustment of a quadrilateral, for which four conditions are necessary, we may employ in the process three angle and one side equation, or two angle and two side equations, or one angle and three side equations; but all four equations cannot be of the same kind. These geometrical conditions may be called "internal conditions" of a triangulation.*

Theoretically, the local and internal conditions should be satisfied together; but practically the number of equations is, in nearly all cases, so great that they must be solved separately. The internal conditions, especially, rise rapidly to an unmanageable number, when primary series or chains of triangulation have an extent of several hundred miles.

A third kind of errors, to which the title of this article specially refers, involves those external conditions which, for instance, require a secondary triangulation to *fit* exactly in the space left for it by a primary triangulation, or those conditions for any triangulation forming a circuit and returning into itself, which are needed for *identity of position* of the starting and terminating lines. These conditions have been termed "external conditions;" and these demand now our special attention. They exist in all cases when a triangulation forms a circuit or returns into itself, and

---

The probable error of a direction is found by—

$$\epsilon_{,} = \sqrt{\frac{0.455\ \Sigma\ \Delta^2}{(s-1)\ \text{diagonal co-efficient.}}}$$

	Pine Mt.	Deakyne.	Buck.
$\Sigma\ \Delta^2$	7.9	18.0	9.7
Diagonal co-efficient	7	13	6
s or number of observations or series	14	26	12
$0.455\ \Sigma\ \Delta^2$	3.59	8.15	4.41
$(s-1)$ diagonal co-efficient	91	325	66
$\epsilon_{,}^2$	0.0395	0.0252	0.0668
$\epsilon_{,}$	±0″.19	±0″.16	±0″.26

In this case, the above results may be verified as follows: Probable error of first *angle* (Pine Mt., Deakyne) $r = \sqrt{\frac{0.455 \times 32.6}{14 \times 13}} = \pm 0''.28$; and of the second angle (Deakyne, Buck) $r_{,} = \sqrt{\frac{0.455 \times 38.2}{12 \times 11}} = \pm 0.36$; as found by the ordinary expression—

$$\sqrt{\frac{0.455\ \Sigma\ \Delta^2}{n\ (n-1)}}$$

Hence, probable error of the first direction (Pine Mt.) $\frac{\pm 0.28}{\sqrt{2}} = \pm 0''.20$; and of the third direction (Buck) $\frac{\pm 0.36}{\sqrt{2}} = \pm\ 0''.26$; and with consideration of the sum of the weights derived for the middle or common direction, the probable error of Deakyne $= \frac{1}{\sqrt{2}} \cdot \frac{rr_{,}}{\sqrt{r^2 + r_{,}^2}} = \pm 0''.16$ as above.

Having found $\epsilon_{,}$, the determination of weights for each of the directions of the sides of a triangle is carried out as shown in the Report for 1864, p. 129, Art. 9.

* For method and example, see Coast Survey Report for 1854, Appendix No. 33, pp. 79 to 86, Art. C; also, Report for 1864, Appendix No. 14, pp. 129 and foll., Art. 11.

incloses an area bounded by a spherical polygon; also in cases where a given triangulation joins two others, *relatively fixed;* also, when a given triangulation is required to terminate on a given line or at a given station, fixed (say astronomically) in position.

In general, a point on the earth's surface, in order to be fixed, requires the knowledge of two co-ordinates. Hence a given line, to be determined in length and position, will require four data. In any *single* circuit, the number of "external conditions" therefore cannot exceed four. To fix our ideas, we may refer to the case of triangulation presented in the survey which, starting from Cape Henlopen, proceeds up the Delaware Bay to near the head of Chesapeake Bay, and thence down its whole extent to Cape Charles, from which a tertiary triangulation skirts the sea-coast, and finally re-enters at Cape Henlopen.* The distance through the axis of the principal triangulation from Cape Henlopen to the head of Chesapeake Bay and down to Cape Charles is 283 statute miles, and the distance between the capes connected by subordinate triangulation is 127 statute miles. The whole circuit, therefore, extends over 410 miles. In this case, the errors must be dispersed over the subordinate work only, the principal triangulation being relatively perfect. The geodetic position of the line Cape Charles to East Smith is fixed by the principal triangulation, and after computing successively the latitudes and longitudes of the trigonometrical points along the sea-coast, the geodetic position of the line Cape Henlopen to Lewes Entrance is reached, and the condition to be satisfied is to make the position of this line identical with that assigned to it in the principal triangulation of Delaware Bay.

The four conditions to be satisfied for closing a circuit may be represented by the following equations: (1) The length equation, which secures the reproduction of the original *length* of the junction line, after computing through the circuit; (2) the azimuth equation, which secures the identity in direction of the line; (3) the latitude equation and (4) the longitude equation, which secure the identity in geographical position of one terminal point of the junction line, and consequently, by previous conditions, also of the other terminal point, and hence of the whole line.

The equations (1) and (2) have been frequently employed, especially (1), which enters whenever two or more base-lines have to be brought into accord, and is referred to in the Report for 1854 (p. *81).† Equation (2), which comes into use when azimuths are to be adjusted, is fully explained and illustrated by an example in the Report for 1868, Appendix No. 8, pp. 140 to 143. In all cases where extreme accuracy is not needed, and after equations (1) and (2) have been satisfied, together with all the "internal" conditions of a re-entering triangulation, it is quite sufficient, especially when the outstanding differences in latitude and longitude or constants of equations (3) and (4) are small, to make simply a proportional distribution of these respective discrepancies; that in latitude according to the longitudes of the intervening points, and that in longitude according to the latitudes of the intervening points, or it may be done as in the case referred to in the Report for 1868. When such an approximate process is not admissible, the four external equations must be treated together with the internal equations.

Let

φ=the latitude of a starting point;

λ=the longitude of the same;

φ_n and λ_n=corresponding quantities for a terminal point.

Then, in accordance with our usual formulæ for the computation of the geodetic latitudes and longitudes (Report for 1860, Appendix No. 36), after omitting terms involving the square and higher powers of the distance k,

$$\Delta\varphi=\varphi_n-\varphi=-k\,\mathrm{B}\cos\alpha$$
$$\Delta\lambda=\lambda_n-\lambda=k\,\mathrm{A}_n\sec\varphi_n\sin\alpha$$

where $\mathrm{B}=\rho^{-1}(\text{arc }1'')^{-1}$ and $\mathrm{A}_n=\mathrm{N}^{-1}(\text{arc }1'')^{-1}$, both tabular quantities.

Conforming to the notation‡ in use in the survey, the establishment of the latitude and longi-

* See, for instance, Sketch No. 4 in Coast Survey Report for 1870, where, however, the triangulation of Delaware Bay is not shown, for which the report for 1851 may be consulted.

† See, also, Puissant's Geodesy, 3d edition, Vol. I, Art 207. Paris, 1842.

‡ An angle 1.2.3 is designated by the difference of its two azimuthal directions $-\frac{1}{2}+\frac{3}{2}$. A correction to the angle is designated by the difference of the corrections to its directions, or by $-\left(\frac{1}{2}\right)+\left(\frac{3}{2}\right)$, the brackets indicating a correction. The length of a side, 4 to 5, is indicated by two points placed between the numbers, thus 4..5; and a correction to its length by (4..5).

tude equations, as developed* by Mr. M. H. Doolittle, together with his methods of facilitating the joint solution of all the equations, is as follows:

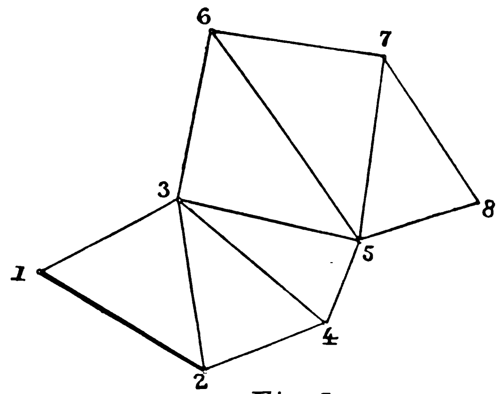


Fig. 1.

"The latitudes and longitudes of the points 1, 2, and 8 are supposed to be established; and those of the intermediate points to require adjustment, the computed position of 8 differing from the established position.

"The corrections in latitude and longitude required to be made to the computed position of the terminal station may be regarded as functions of appropriate corrections to the logarithms of the lengths and to the azimuths of the portions of a broken line connecting the terminal point with the initial base. These corrections to the logarithms of lengths and to the azimuths are functions of corrections to observed directions.

"For distinction, let corrections required as functions of corrections to logarithms of lengths be denoted by $\varDelta$; and those required as functions of corrections to azimuths by $\varDelta'$.

"Suppose that errors requiring corrections $= -\left(\begin{matrix}2\\3\end{matrix}\right)+\left(\begin{matrix}1\\3\end{matrix}\right)$ and $-\left(\begin{matrix}3\\1\end{matrix}\right)$ are made in observing the angles 2.3.1 and 3.1.2 respectively, whereby the ratio of lengths $\frac{2\,.\,.\,3}{1\,.\,.\,2}$ is vitiated. All distances and differences of latitude and longitude depending thereupon are also thereby vitiated in direct proportion to their magnitudes. Accordingly, employing $\varDelta\,(\varphi_8-\varphi_2)$ and $\varDelta\,(\lambda_8-\lambda_2)$ to denote corrections required on account of this vitiation, we have

$$\frac{\varphi_8-\varphi_2}{\frac{2\,.\,.\,3}{1\,.\,.\,2}}=\frac{\varDelta\,(\varphi_8-\varphi_2)}{\varDelta\left(\frac{2\,.\,.\,3}{1\,.\,.\,2}\right)} \quad \text{and} \quad \frac{\lambda_8-\lambda_2}{\frac{2\,.\,.\,3}{1\,.\,.\,2}}=\frac{\varDelta\,(\lambda_8-\lambda_2)}{\varDelta\left(\frac{2\,.\,.\,3}{1\,.\,.\,2}\right)}$$

"It will be sufficiently precise to take $\varphi_8-\varphi_2$ and $\lambda_8-\lambda_2$ in minutes in the left hand members of these equations. Let accents be attached to these and similar quantities to show whether they are taken in minutes or seconds. Then, since

$$\varDelta\left(\frac{2\,.\,.\,3}{1\,.\,.\,2}\right)=\frac{2\,.\,.\,3\ \varDelta\log\frac{2\,.\,.\,3}{1\,.\,.\,2}}{1\,.\,.\,2\times 0.4343}$$

we shall have

$$\varDelta\,(\varphi_8-\varphi_2)''=\frac{60\,(\varphi_8-\varphi_2)'\,\varDelta\log\frac{2\,.\,.\,3}{1\,.\,.\,2}}{0.4343} \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$\varDelta\,(\lambda_8-\lambda_2)''=\frac{60\,(\lambda_8-\lambda_2)'\,\varDelta\log\frac{2\,.\,.\,3}{1\,.\,.\,2}}{0.4343} \quad \ldots\ldots\ldots\ldots \quad (2)$$

"Denoting by Dif. log sin the tabular difference of log sin for $1''$, we have—

$$\varDelta\log\frac{2\,.\,.\,3}{1\,.\,.\,2}=\text{Dif. log sin}\,3\,.\,1\,.\,2\left[-\left(\begin{matrix}3\\1\end{matrix}\right)\right]-\text{Dif. log sin}\,2\,.\,3\,.\,1\left[-\left(\begin{matrix}2\\3\end{matrix}\right)+\left(\begin{matrix}1\\3\end{matrix}\right)\right]$$

and this value of $\varDelta\log\frac{2\,.\,.\,3}{1\,.\,.\,2}$ being substituted in (1) and (2), we have expressions for corrections in latitude and longitude in terms of corrections to directions.

"If a length equation following the same broken line has already been formed, the process may be abridged. Equations (1) and (2) readily reduce to

$$724\,\varDelta\,(\varphi_8-\varphi_2)''=(\varphi_8-\varphi_2)'\times 100000\,\varDelta\log\frac{2\,.\,.\,3}{1\,.\,.\,2} \quad \ldots\ldots\ldots \quad (3)$$

$$724\,\varDelta\,(\lambda_8-\lambda_2)''=(\lambda_8-\lambda_2)'\times 100000\,\varDelta\log\frac{2\,.\,.\,3}{1\,.\,.\,2} \quad \ldots\ldots\ldots \quad (4)$$

* In October, 1874.

and if, in forming the length equation, all terms have been multipled, as usual, by 100000, the proper expressions for 100000 $\Delta \log \frac{2\,..\,3}{1\,..\,2}$ may be obtained by simply prefixing to each of the correction-symbols $\binom{3}{1}$, $\binom{2}{3}$, and $\binom{1}{3}$ the same co-efficient and algebraic sign that it has in the length equation.

"In like manner

$$724\,\Delta(\varphi_8 - \varphi_5)'' = (\varphi_8 - \varphi_5)' \times 100000\,\Delta \log \frac{3\,..\,5}{2\,..\,3}$$

$$724\,\Delta(\lambda_8 - \lambda_5)'' = (\lambda_8 - \lambda_5)' \times 100000\,\Delta \log \frac{3\,..\,5}{2\,..\,3}$$

$$\Delta \log \frac{3\,..\,5}{2\,..\,3} = \text{Dif. log sin } 3\,.\,2\,.\,4\left[-\binom{3}{2}+\binom{4}{2}\right] - \text{Dif. log sin } 3\,.\,4\,.\,2\left[-\binom{2}{4}+\binom{3}{4}\right]$$

$$+ \text{Dif. log sin } 3\,.\,4\,.\,5\left[-\binom{3}{4}+\binom{5}{4}\right] - \text{Dif. log sin } 4\,.\,5\,.\,3\left[-\binom{4}{5}+\binom{3}{5}\right]$$

and the proper co efficients and algebraic signs can be taken from the length equation.

"All the azimuths between 2 and 8 are vitiated equally by an error in observing the angle 1.2.3; and the effect on the computed position of 8 is the same as though 8 had been observed directly from 2 with equal error. Suppose, then, that these two points are joined by a straight line (or great circle arc). Denote its length by 2 .. 8 and its azimuth by $\genfrac{}{}{0pt}{}{8}{2}$. Then, omitting small terms, we have

$$\varphi_8 - \varphi_2 = -\,B_2\,2\,..\,8 \cos \genfrac{}{}{0pt}{}{8}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$$\lambda_8 - \lambda_2 = +\,A_8 \sec \varphi_8\,2\,..\,8 \sin \genfrac{}{}{0pt}{}{8}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

"Differentiating,

$$d\,(\varphi_8 - \varphi_2) = +\,B_2\,2\,..\,8 \sin \genfrac{}{}{0pt}{}{8}{2}\, d\genfrac{}{}{0pt}{}{8}{2}$$

$$d\,(\lambda_8 - \lambda_2) = +\,A_8 \sec \varphi_8\,2\,..\,8 \cos \genfrac{}{}{0pt}{}{8}{2}\, d\genfrac{}{}{0pt}{}{8}{2}$$

"Passing to finite differences with a unit of 1″, and substituting the correction $+\binom{3}{2}$ for $\Delta\genfrac{}{}{0pt}{}{8}{2}$,

$$\Delta'(\varphi_8 - \varphi_2) = +\,B_2\,2\,..\,8 \sin \genfrac{}{}{0pt}{}{8}{2} \sin 1''\binom{3}{2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

$$\Delta'(\lambda_8 - \lambda_2) = +\,A_8 \sec \varphi_8\,2\,..\,8 \cos \genfrac{}{}{0pt}{}{8}{2} \sin 1''\binom{3}{2} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

"Combining (7) with (6) and (8) with (5), and taking the factors $\varphi_8 - \varphi_2$ and $\lambda_8 - \lambda_2$ in minutes,

$$\Delta'(\varphi_8 - \varphi_2)'' = +\,60\,\frac{B_2}{A_8} \cos \varphi_8 \sin 1''\,(\lambda_8 - \lambda_2)'\binom{3}{2} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

$$\Delta'(\lambda_8 - \lambda_2)'' = -\,60\,\frac{A_8}{B_2} \sec \varphi_8 \sin 1''\,(\varphi_8 - \varphi_2)'\binom{3}{2} \quad . \quad . \quad . \quad . \quad . \quad (10)$$

"In like manner

$$\Delta' (\varphi_8-\varphi_5)''=+60\frac{B_5}{A_8}\cos\varphi_8\sin 1''(\lambda_8-\lambda_5)'\Big[-\Big(\tfrac{2}{3}\Big)+\Big(\tfrac{5}{3}\Big)\Big]$$

$$\Delta' (\lambda_8-\lambda_5)''=-60\frac{A_8}{B_5}\sec\varphi_8\sin 1''(\varphi_8-\varphi_5)'\Big[-\Big(\tfrac{2}{3}\Big)+\Big(\tfrac{5}{3}\Big)\Big]$$

"In order to obtain general formulæ, let n represent the computed position and n' the correct position of the terminal station; and let c, d, e represent successively every case of three consecutive stations on the line $1..2\ .\ .\ .\ .\ .\ .\ n$. Also, let

$$+43430\frac{B}{A_n}\cos\varphi_n\sin 1''=a_1 \text{ and } -43430\frac{A_n}{B}\sec\varphi_n\sin 1''=a_2.$$

"We shall then have

$$724\,\Delta(\varphi_n-\varphi_d)''=+(\varphi_n-\varphi_d)'\times 100000\,\Delta\log\frac{d..e}{c..d}\quad . . . . \quad (11)$$

$$724\,\Delta(\lambda_n-\lambda_d)''=+(\lambda_n-\lambda_d)'\times 100000\,\Delta\log\frac{d..e}{c..d}\quad . . . . \quad (12)$$

$$724\,\Delta'(\varphi_n-\varphi_d)''=+a_1(\lambda_n-\lambda_d)'\Big[-\Big(\tfrac{c}{d}\Big)+\Big(\tfrac{e}{d}\Big)\Big]\quad . . . . \quad (13)$$

$$724\,\Delta'(\lambda_n-\lambda_d)''=+a_2(\varphi_n-\varphi_d)'\Big[-\Big(\tfrac{c}{d}\Big)+\Big(\tfrac{e}{d}\Big)\Big]\quad . . . . \quad (14)$$

$$0=+724(\varphi_n-\varphi_{n'})''+\Sigma\,724\,\Delta(\varphi_n-\varphi_d)''+\Sigma\,724\,\Delta'(\varphi_n-\varphi_d)''\quad . . . . . . \quad (15)$$

$$0=+724(\lambda_n-\lambda_{n'})''+\Sigma\,724\,\Delta'(\lambda_n-\lambda_d)''+\Sigma\,724\,\Delta'(\lambda_n-\lambda_d)''\quad . . . . . . \quad (16)$$

"Or,

$$0=+724(\varphi_n-\varphi_{n'})''+\Sigma\Big[(\varphi_n-\varphi_d)'\times 100000\,\Delta\log\frac{d..e}{c..d}\Big]+\Sigma\Big\{a_1(\lambda_n=\lambda_d)'\Big[-\Big(\tfrac{c}{d}\Big)+\Big(\tfrac{e}{d}\Big)\Big]\Big\}\quad . \ (17)$$

$$0=+724(\lambda_n-\lambda_{n'})''+\Sigma\Big[(\lambda_n-\lambda_d)'\times 100000\,\Delta\log\frac{d..e}{c..d}\Big]+\Sigma\Big\{a_2(\varphi_n-\varphi_d)'\Big[-\Big(\tfrac{c}{d}\Big)+\Big(\tfrac{e}{d}\Big)\Big]\Big\}\quad . \ (18)$$

"In these equations, $\varphi_n-\varphi_{n'}$ and $\lambda_n-\lambda_{n'}$ are taken in seconds, and $\varphi_n-\varphi_d$ and $\lambda_n-\lambda_d$ in minutes or seconds, as the accents indicate.

"The values of a_1 and a_2 are as follows:

ϕ	24°	28°	32°	36°	40°	44°	48°
a_1......	+0.193	+0.187	+0.179	+0.171	+0.162	+0.152	+0.141
a_2......	−0.229	−0.237	−0.247	−0.259	−0.274	−0.292	−0.314

"These formulæ are perfectly general, and apply to any broken line connecting a terminal point with an initial base. The more direct line 1...2...4...5...8 might be chosen with the advantage of diminution in the number of stations; but on account of the increased length of expressions for $\Delta\log\frac{4..5}{2..4}$, &c., it is somewhat more convenient to employ the same line which is most conveniently employed in forming the length equation.

"NOTE.—In the azimuth equation, when the longitude error is known the azimuth error should be increased by $+\sin\varphi\,(\lambda_n-\lambda_{n'})$.

ILLUSTRATION.

"In the survey on Long Island from Ruland–Tashua to McSparran–East Rock (United States

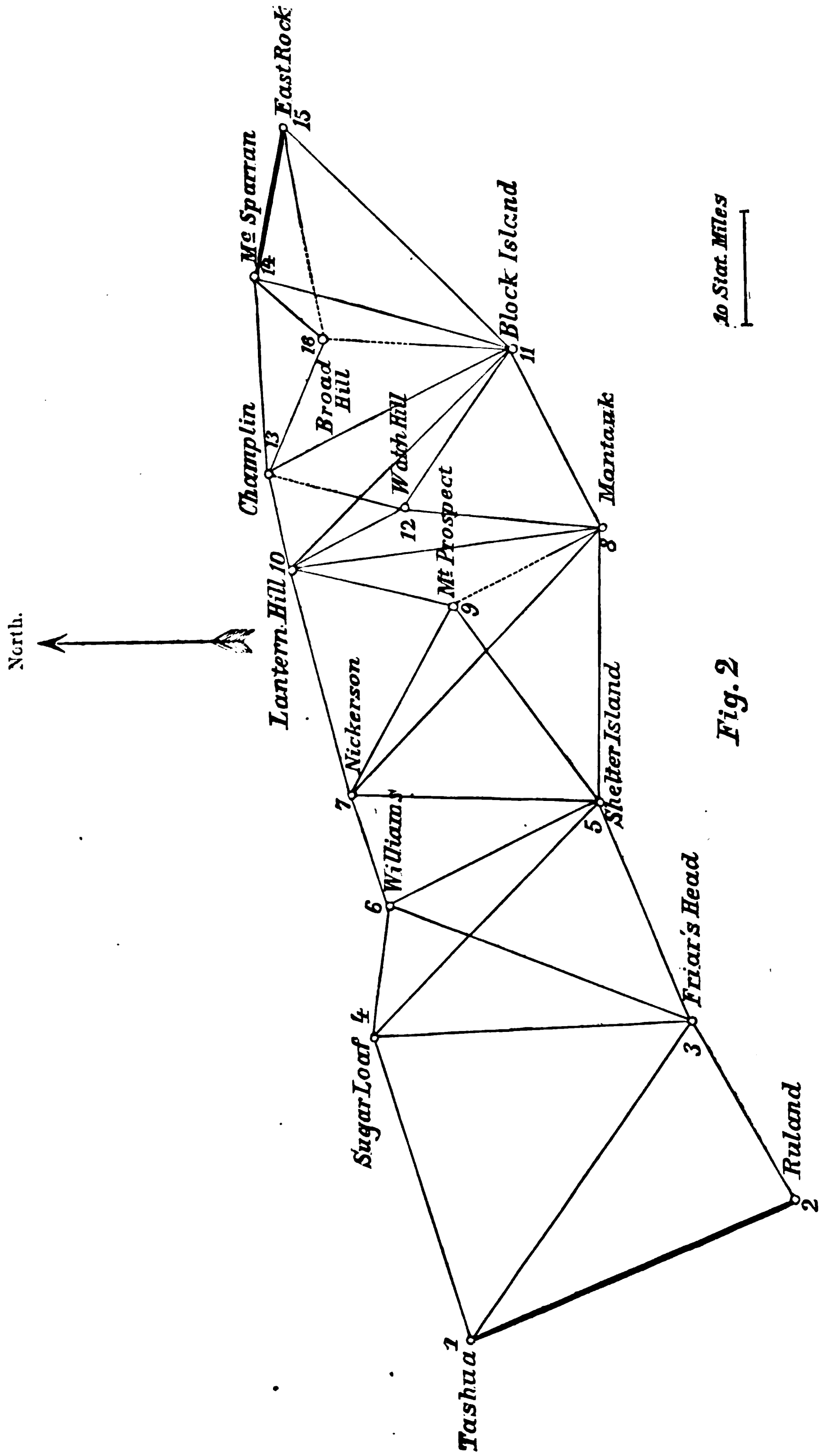


Fig. 2

Coast Survey Report, 1868, p. 140, plate 6), the broken line may be taken as connecting Ruland with McSparran. Observe that Ruland, though at the beginning of the line, is denoted by 2, the

more appropriate number 1 having been given to Tashua. The length and azimuth equations head p. 143 of the Report for 1868. The latitude and longitude equations are formed as follows:

$$\varphi_n = \varphi_{14} = 41^\circ\ 29'.7. \qquad \lambda_n = \lambda_{14} = 71^\circ\ 27'.1.$$

d	ϕ_d	λ_d	$(\phi_n - \phi_d)'$	$(\lambda_n - \lambda_d)'$
	° ′	° ′	′	′
1. Tashua	41 15.6	73 14.7	+ 14.1	−107.6
3. Friar's Head	40 58.2	72 43.4	+ 31.5	− 76.3
4. Sugar Loaf	41 22.5	72 43.6	+ 07.2	− 76.5
5. Shelter Island	41 04.6	72 21.3	+ 25.1	− 54.2
7. Nickerson	41 23.9	72 19.3	+ 05.8	− 52.2
8. Montauk	41 03.9	71 54.0	+ 25.8	− 26.9
10. Lantern Hill	41 27.6	71 56.3	+ 02.1	− 29.2
11. Block Island	41 10.5	71.35.2	+ 19.2	− 08.1

$$a_1 = +\ 0.16 \qquad a_2 = -\ 0.28$$

$$\varphi_n - \varphi_{n'} = +0''.007 \qquad 724\ (\varphi_n - \varphi_{n'}) = +\ 5''.068$$

$$\lambda_n - \lambda_{n'} = +0''.038 \qquad 724\ (\lambda_n - \lambda_{n'}) = +27''.512$$

d	$100000\ \Delta \log \frac{d\ .\ .\ e}{c\ .\ .\ d}$	$-\binom{c}{d}+\binom{e}{d}$
1	$+0.03\binom{3}{2}-0.10\binom{1}{3}+0.10\binom{2}{3}$	$+\binom{3}{1}$
3	$-0.16\binom{4}{1}+0.16\binom{3}{1}+0.06\binom{3}{4}-0.06\binom{1}{4}$	$-\binom{1}{3}+\binom{4}{3}$
4	$-0.08\binom{4}{3}+0.08\binom{5}{3}+0.09\binom{3}{5}-0.09\binom{4}{5}$	$-\binom{3}{4}+\binom{5}{4}$
5	$-0.26\binom{6}{4}+0.26\binom{5}{4}-0.02\binom{7}{6}-0.10\binom{5}{6}+0.12\binom{4}{6}+0.08\binom{5}{7}-0.08\binom{6}{7}$	$-\binom{4}{5}+\binom{7}{5}$
7	$-0.01\binom{7}{5}+0.01\binom{8}{5}+0.22\binom{5}{8}-0.22\binom{7}{8}$	$-\binom{5}{7}+\binom{8}{7}$
8	$-0.13\binom{10}{7}+0.13\binom{8}{7}+0.02\binom{8}{10}-0.02\binom{7}{10}$	$-\binom{7}{8}+\binom{10}{8}$
10	$-0.08\binom{10}{8}+0.08\binom{11}{8}+0.07\binom{8}{11}-0.07\binom{10}{11}$	$-\binom{8}{10}+\binom{11}{10}$
11	$-0.12\binom{13}{10}+0.12\binom{11}{10}+0.04\binom{10}{13}+0.04\binom{11}{13}-0.08\binom{14}{13}+0.07\binom{11}{14}-0.07\binom{13}{14}$	$-\binom{10}{11}+\binom{14}{11}$

d	$724\ \Delta\ (\phi_n - \phi_d)'$	$724\ \Delta'\ (\phi_n - \phi_d)'$
1	$+0.4\binom{3}{2}-1.4\binom{1}{3}+1.4\binom{2}{3}$	$-17.2\binom{3}{1}$
3	$-5.0\binom{4}{1}+5.0\binom{3}{1}+1.9\binom{3}{4}-1.9\binom{1}{4}$	$+12.2\binom{1}{3}-12.2\binom{4}{3}$
4	$-0.6\binom{4}{3}+0.6\binom{5}{3}+0.6\binom{3}{5}-0.6\binom{4}{5}$	$+12.2\binom{3}{4}-12.2\binom{5}{4}$
5	$-6.5\binom{6}{4}+6.5\binom{5}{4}-0.5\binom{7}{6}-2.5\binom{5}{6}+3.0\binom{4}{6}+2.0\binom{5}{7}-2.0\binom{6}{7}$	$+\ 8.7\binom{4}{5}-\ 8.7\binom{7}{5}$
7	$-0.1\binom{7}{5}+0.1\binom{8}{5}+1.3\binom{5}{8}-1.3\binom{7}{8}$	$+\ 8.4\binom{5}{7}-\ 8.4\binom{8}{7}$
8	$-3.4\binom{10}{7}+3.4\binom{8}{7}+0.5\binom{8}{10}-0.5\binom{7}{10}$	$+\ 4.3\binom{7}{8}-\ 4.3\binom{10}{8}$
10	$-0.2\binom{10}{8}+0.2\binom{11}{8}+0.1\binom{8}{11}-0.1\binom{10}{11}$	$+\ 4.7\binom{8}{10}-\ 4.7\binom{11}{10}$
11	$-2.3\binom{13}{10}+2.3\binom{11}{10}+0.8\binom{10}{13}+0.8\binom{11}{13}-1.5\binom{14}{13}+1.3\binom{11}{14}-1.3\binom{13}{14}$	$+\ 1.3\binom{10}{11}-\ 1.3\binom{14}{11}$

d	$724\,\Delta\,(\lambda_n - \lambda_d)'$	$724\,\Delta'\,(\lambda_n - \lambda_d)'$
1	$-3.2\binom{3}{2}+10.8\binom{1}{3}-10.8\binom{2}{3}$	$-3.9\binom{3}{1}$
3	$+12.2\binom{4}{1}-12.2\binom{3}{1}-4.6\binom{3}{4}+4.6\binom{1}{4}$	$+8.8\binom{1}{3}-8.8\binom{4}{3}$
4	$+6.1\binom{4}{3}-6.1\binom{5}{3}-6.8\binom{3}{5}+6.8\binom{4}{5}$	$+2.0\binom{3}{4}-2.0\binom{5}{4}$
5	$+14.1\binom{6}{4}-14.1\binom{5}{4}+1.1\binom{7}{6}+5.4\binom{5}{6}-6.5\binom{4}{6}-4.3\binom{5}{7}+4.3\binom{6}{7}$......	$+7.0\binom{4}{5}-7.0\binom{7}{5}$
7	$+0.5\binom{7}{5}-0.5\binom{8}{5}-11.4\binom{5}{8}+11.4\binom{7}{8}$	$+1.6\binom{5}{7}-1.6\binom{8}{7}$
8	$+3.5\binom{10}{7}-3.5\binom{8}{7}-0.5\binom{8}{10}+0.5\binom{7}{10}$	$+7.2\binom{7}{8}-7.2\binom{10}{8}$
10	$+2.3\binom{10}{8}-2.3\binom{11}{8}-2.0\binom{8}{11}+2.0\binom{10}{11}$	$+0.1\binom{8}{10}-0.1\binom{11}{10}$
11	$+1.0\binom{13}{10}-1.0\binom{11}{10}-0.3\binom{10}{13}-0.3\binom{11}{13}+0.6\binom{14}{13}-0.6\binom{11}{14}+0.6\binom{13}{14}$	$+5.4\binom{10}{11}-5.4\binom{14}{11}$

Equation XXVII. (φ.)

$$
\begin{aligned}
0=&+5.068+0.4\binom{3}{2}+10.8\binom{1}{3}+1.4\binom{2}{3}-5.0\binom{4}{1}-12.2\binom{3}{1}+14.1\binom{3}{4}-1.9\binom{1}{4}\\
&-12.8\binom{4}{3}+0.6\binom{5}{3}+0.6\binom{3}{5}+8.1\binom{4}{5}-6.5\binom{6}{4}-5.7\binom{5}{4}-0.5\binom{7}{6}\\
&-2.5\binom{5}{6}+3.0\binom{4}{6}+10.4\binom{5}{7}-2.0\binom{6}{7}-8.8\binom{7}{5}+0.1\binom{8}{5}+1.3\binom{5}{8}\\
&+3.0\binom{7}{8}-3.4\binom{10}{7}-5.0\binom{8}{7}+5.2\binom{8}{10}-0.5\binom{7}{10}-4.5\binom{10}{8}+0.2\binom{11}{8}\\
&+0.1\binom{8}{11}+1.2\binom{10}{11}-2.3\binom{13}{10}-2.4\binom{11}{10}+0.8\binom{10}{13}+0.8\binom{11}{13}-1.5\binom{14}{13}\\
&+1.3\binom{11}{14}+1.3\binom{13}{14}-1.3\binom{14}{11}.
\end{aligned}
$$

Equation XXVIII. (λ.)

$$
\begin{aligned}
0=&+27.512-3.2\binom{3}{2}+19.6\binom{1}{3}-10.8\binom{2}{3}+12.2\binom{4}{1}-16.1\binom{3}{1}-2.6\binom{3}{4}+4.6\binom{1}{4}\\
&-2.7\binom{4}{3}-6.1\binom{5}{3}-6.8\binom{3}{5}+13.8\binom{4}{5}+14.1\binom{6}{4}-16.1\binom{5}{4}+1.1\binom{7}{6}\\
&+5.4\binom{5}{6}-6.5\binom{4}{6}-2.7\binom{5}{7}+4.3\binom{6}{7}-6.5\binom{7}{5}-0.5\binom{8}{5}-11.4\binom{5}{8}\\
&+18.6\binom{7}{8}+3.5\binom{10}{7}-5.1\binom{8}{7}-0.4\binom{8}{10}+0.5\binom{7}{10}-4.9\binom{10}{8}-2.3\binom{11}{8}\\
&-2.0\binom{8}{11}+7.4\binom{10}{11}+1.0\binom{13}{10}-1.1\binom{11}{10}-0.3\binom{10}{13}-0.3\binom{11}{13}+0.6\binom{14}{13}\\
&-0.6\binom{11}{14}+0.6\binom{13}{14}-5.4\binom{14}{11}.
\end{aligned}
$$

"While the preceding formulæ are theoretically correct and complete, there are systematic antagonisms which necessarily render the equations difficult of solution. For example, the side co efficient between the length equation and the longitude equation is equal to

$$\Sigma\,(\lambda_n-\lambda_d)'\,(\text{length eq. co-ef.})^2+\Sigma\left\{a_2\,(\varphi_n-\varphi_d)'\left[-\binom{c}{d}+\binom{e}{d}\right]\right\}(\text{length eq. co-ef.});$$

and unless the stations are nearly equally distributed on both sides of the meridian of station n,

$(\lambda_n-\lambda_d)'$ will have predominantly the same algebraic sign; and the first term of the above expression will be very large. The second term is as likely to increase it as to diminish it. In any case, the side co-efficients of the length equation with the latitude and longitude equations cannot both be small.

"The following artifices obviate this and some similar difficulties.

"Let the line $1\,..\,2\,..\,3\,.....\,n$ include both points of the terminal as well as of the initial base. The length equation will then be of the form

$$0=\Delta\, k+\Sigma\, 100000\,\Delta \log \frac{d\,..\,e}{c\,..\,d}; \qquad \text{(19)}$$

and the azimuth equation following the same line will be of the form

$$0=\Delta\, a+\left[-\binom{c}{d}+\binom{e}{d}\right] \qquad \text{(20)}$$

"Determine a point h of approximate mean latitude and longitude in regard to all the stations except 1 and n. (It need not be on any line of the survey.) Multiply (19) by $(\varphi_n-\varphi_h)'$, and (20) by $a_1\,(\lambda_n-\lambda_h)'$; and add the products, giving

$$0=(\varphi_n-\varphi_h)'\,\Delta\, k+a_1\,(\lambda_n-\lambda_h)'\,\Delta\, a$$
$$+\Sigma\left[(\varphi_n-\varphi_h)'\times 100000\,\Delta \log \frac{d\,..\,e}{c\,..\,d}\right]+\Sigma\left\{a_1\,(\lambda_n-\lambda_h)'\left[-\binom{c}{d}+\binom{e}{d}\right]\right\} \qquad \text{(21)}$$

"Also multiply (19) by $(\lambda_n+\lambda_h)'$, and (20) by $a_2\,(\varphi_n-\varphi_h)'$; and add the products, giving

$$0=(\lambda_n-\lambda_h)'\,\Delta\, k+a_2\,(\varphi_n-\varphi_h)'\,\Delta a$$
$$+\Sigma\left[(\lambda_n-\lambda_h)'\times 100000\,\Delta \log \frac{d\,..\,e}{c\,..\,d}\right]+\Sigma\left\{a_2(\varphi_n-\varphi_h)'\left[-\binom{c}{d}+\binom{e}{d}\right]\right\} \qquad \text{(22)}$$

"Subtracting (21) from (17), and (22) from (18)—

$$0=724\,(\varphi_n-\varphi_{n'})''-(\varphi_n-\varphi_h)'\,\Delta\, k-a_1(\lambda_n-\lambda_h)'\,\Delta a$$
$$+\Sigma\left[(\varphi_h-\varphi_d)'\times 100000\,\Delta \log \frac{d\,..\,e}{c\,..\,d}\right]+\Sigma\left\{a_1(\lambda_h-\lambda_d)'\left[-\binom{c}{d}+\binom{e}{d}\right]\right\} \qquad \text{(23)}$$

$$0=724\,(\lambda_n-\lambda_{n'})''-(\lambda_n-\lambda_h)'\,\Delta k-a_2\,(\varphi_n-\varphi_h)'\,\Delta\, a$$
$$+\Sigma\left[(\lambda_h-\lambda_d)'\times 100000\,\Delta \log \frac{d\,..\,e}{c\,..\,d}\right]+\Sigma\left\{a_2(\varphi_h-\varphi_d)'\left[-\binom{c}{d}-\binom{e}{d}\right]\right\} \qquad \text{(24)}$$

"These equations are to be substituted for (17) and (18).

"There is a systematic antagonism between the angle equations and the azimuth equation as commonly established, which becomes very troublesome when length, latitude, and longitude are also to be adjusted.

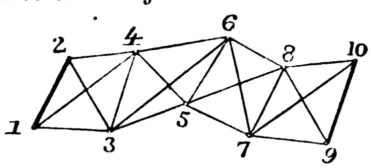


Fig. 3.

In a chain of quadrilaterals, like the accompanying figure, if four azimuth equations be formed with routes as follows:

1 .. 3 .. 5 .. 7 .. 9
2 .. 4 .. 6 .. 8 .. 10
1 .. 4 .. 5 .. 8 .. 9
2 .. 3 .. 6 .. 7 .. 10

the sum of these four equations will form an equation by which the azimuth will be adjusted without changing the sum of the three angles in any triangle. The side co-efficients will each $=0$.

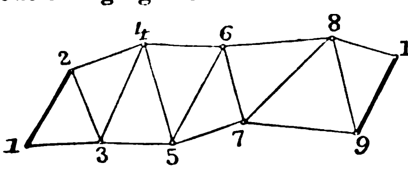


Fig. 4.

In a string of triangles like this, if three azimuth equations be formed with the following routes:

1 .. 3 .. 5 .. 7 .. 9
2 .. 4 .. 6 .. 8 .. 10
2 .. 3 .. 4 .. 5 .. 6 .. 7 .. 8 .. 9

the sum of the third + twice the first + twice the second will adjust the azimuth without affecting the angle adjustment of any triangle except the first and last of the series.

"It is a general principle that the combination of routes should inclose each triangle, as a river forks and incloses an island. Pursuing this simile, imagine a triangle encompassed by two "channels;" denote the number of routes in each channel by arrows, repeated when the same route passes along two sides of the triangle. If the number of arrows in one channel is equal to that of those in the other, the side co-efficient $= 0$. If they are nearly equal, it is small.

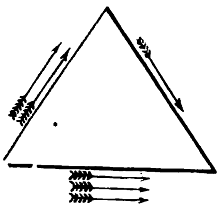


Fig. 5.

"The diagonal co-efficient derived from the azimuth equation increases rapidly with the number of routes; and if it should not be practicable by this method to extinguish the side co-efficients in a complicated figure, they may still be rendered comparatively insignificant.

"By the following general method, any side co-efficients may be extinguished:

"Suppose given the four conditional equations—

$$
\begin{aligned}
&1.\ 0 = a_0 + a_1 v_1 + a_2 v_2 + a_3 v_3, \text{ \&c.}\\
&2.\ 0 = b_0 + b_1 v_1 + b_2 v_2 + b_3 v_3, \text{ \&c.}\\
&3.\ 0 = c_0 + c_1 v_1 + c_2 v_2 + c_3 v_3, \text{ \&c.}\\
&4.\ 0 = d_0 + d_1 v_1 + d_2 v_2 + d_3 v_3, \text{ \&c.}
\end{aligned}
$$

"From these, three other equations are to be obtained and substituted for equations 2, 3, and 4. Distinguishing the substitutes and their co-efficients by accents, let

$$
\begin{aligned}
&\text{Eq. } 2' = \text{Eq. } 2 + u \text{ Eq. } 1\\
&\text{Eq. } 3' = \text{Eq. } 3 + v \text{ Eq. } 1 + w \text{ Eq. } 2\\
&\text{Eq. } 4' = \text{Eq. } 4 + x \text{ Eq. } 1 + y \text{ Eq. } 2 + z \text{ Eq. } 3
\end{aligned}
$$

and the values of u, v, w, x, y, and z are to be so determined as to render $[a\,b']$, $[a\,c']$, $[b'\,c']$, $[a\,d']$, $[b'\,d']$, and $[c'\,d']$, each $= 0$.

"We shall then have

$$
\begin{aligned}
0 &= [a\,b'] = [a\,(b + a\,u)] = [a\,b] + u\,[a\,a]\\
0 &= [a\,c'] = [a\,(c + a\,v + b\,w)] = [a\,c] + v\,[a\,a] + w\,[a\,b]\\
0 &= [b'\,c'] = [(b + a\,u)\,(c + a\,v + b\,w)] = [b\,(c + a\,v + b\,w)] + u\,[a\,(c + a\,v + b\,w)]
\end{aligned}
$$

"The last term $= 0$ by the last preceding equation. Hence

$$0 = [b'\,c'] = [b\,(c + a\,v + b\,w)] = [b\,c] + v\,[a\,b] + w\,[b\,b.]$$

"In like manner

$$
\begin{aligned}
0 &= [a\ \ d'] = [a\,d] + x\,[a\,a] + y\,[a\,b] + z\,[a\,c]\\
0 &= [b'\,d'] = [b\,d] + x\,[a\,b] + y\,[b\,b] + z\,[b\,c]\\
0 &= [c'\,d'] = [c\,d] + x\,[a\,c] + y\,[b\,c] + z\,[c\,c]
\end{aligned}
$$

"Since x, y, and z are independent of u, v, and w, the original equations 2 and 3, with $[a\,b]$, $[a\,c]$, and $[b\,c]$, may be retained, if more convenient, still reducing $[a\,d']$, $[b'\,d']$, and $[c'\,d']$ to 0.

"For the purpose of illustration, it will be best to consider the discrepancies of the Long Island survey, as they existed before the adjustment of azimuth and length; and East Rock will now be regarded as the terminal station n.

"The error in azimuth from East Rock to McSparran was $+ 2''.927$. The error in longitude at East Rock was $+ 0''.049$. Hence, $\Delta\,a = + 2''.927 + 0''.049 \sin \varphi = + 2''.959$.

"The following seven azimuth routes have been selected:

1 . . 4 . . 6 . . 7 . . 10 . . 13 . . 14
2 . . 3 . . 5 . . 8 . . 11 . . 15
2 . . 3 . . 5 . . 8 . . 11 . . 15
1 . . 3 . . 6 . . 5 . . 7 . . 10 . . 11 . . 13 . . 16 . . 14
1 . . 3 . . 6 . . 7 . . 8 . . 12 . . 11 . . 14
1 . . 4 . . 5 . . 9 . . 10 . . 11 . . 14
1 . . 4 . . 5 . . 8 . . 10 . . 13 . . 14

Giving the azimuth equation:

$$
\begin{aligned}
0 = +20''.713 &+2\binom{3}{1}-2\binom{1}{3}+3\binom{4}{1}-3\binom{1}{4}+2\binom{3}{2}-2\binom{2}{3}+2\binom{5}{3}-2\binom{3}{5}+2\binom{6}{3} \\
&-2\binom{3}{6}+2\binom{5}{4}-2\binom{4}{5}+\binom{6}{4}-\binom{4}{6}+\binom{7}{5}-\binom{5}{7}+3\binom{8}{5}-3\binom{5}{8} \\
&+\binom{9}{5}-\binom{5}{9}+\binom{5}{6}-\binom{6}{5}+2\binom{7}{6}-2\binom{6}{7}+\binom{8}{7}-\binom{7}{8}+2\binom{10}{7} \\
&-2\binom{7}{10}+\binom{10}{8}-\binom{8}{10}+2\binom{11}{8}-2\binom{8}{11}+\binom{12}{8}-\binom{8}{12}+\binom{10}{9}-\binom{9}{10} \\
&+2\binom{11}{10}-2\binom{10}{11}+2\binom{13}{10}-2\binom{10}{13}+\binom{13}{11}-\binom{11}{13}+2\binom{14}{11}-2\binom{11}{14}+2\binom{15}{11} \\
&-2\binom{11}{15}+\binom{11}{12}-\binom{12}{11}+2\binom{14}{13}-2\binom{13}{14}+\binom{16}{13}-\binom{13}{16}+\binom{14}{16}-\binom{16}{14}
\end{aligned}
$$

"This gives a diagonal co-efficient = 164; while ten of the seventeen necessary side co-efficients with angle equations = 0; and the other seven = either + 2 or − 2.

"For adjustment of latitude and longitude we find $\varphi_h = +41^\circ\ 15'$ and $\lambda_h = +72^\circ\ 15'$; and construct the following tables:

d.	ϕ_d	λ_d	$(\phi_h - \phi_d)'$	$(\lambda_h - \lambda_d)'$
	° ′	° ′	′	′
1. Tashua	41 15.6	73 14.7	− 0.6	−59.7
3. Friar's Head	40 58.2	72 43.4	+16.8	−28.4
4. Sugar Loaf	41 22.5	72 43.6	− 7.5	−28.6
5. Shelter Island	41 04.6	72 21.3	+10.4	− 6.3
7. Nickerson	41 23.9	72 19.3	− 8.9	− 4.3
8. Montauk	41 03.9	71 54.0	+11.1	+21.0
10. Lantern Hill	41 27.6	71 56.3	−12.6	+18.7
11. Block Island	41 10.5	71 35.2	+ 4.5	+39.8
14. McSparran	41 29.7	71 27.1	−14.7	+47.9

$\varphi_n = \varphi_{15} = 41^\circ\ 27'.0.$ $\quad \varphi_n - \varphi_h = +12'.0.$ $\quad a_1 = +0.16.$

$\lambda_n = \lambda_{15} = 71^\circ\ 11'.3.$ $\quad \lambda_n - \lambda_h = -63'.7.$ $\quad a_2 = -0.28.$

$\Delta a = +2''.959.$ $\quad \Delta k = -0.40.$ $\quad \varphi_n - \varphi_{n'} = -0''.039.$ $\quad \lambda_n - \lambda_{n'} = +6''.049.$

$724\ (\varphi_n - \varphi_{n'})'' - (\varphi_n - \varphi_h)'\ \Delta k - a_1\ (\lambda_n - \lambda_h)'\ \Delta a = +\ 6.722.$

$724\ (\lambda_n - \lambda_{n'})'' - (\lambda_n - \lambda_h)'\ \Delta k - a_2\ (\varphi_n - \varphi_h)'\ \Delta a = +\ 19.938.$

d	$100000\ \Delta \log \frac{d\ .\ .\ e}{c\ .\ .\ d}$	$-\binom{c}{d}+\binom{e}{d}$
1	$+0.03\binom{3}{2}-0.10\binom{1}{3}+0.10\binom{2}{3}$	$+\binom{3}{1}$
3	$-0.16\binom{4}{1}+0.16\binom{3}{1}+0.06\binom{3}{4}-0.06\binom{1}{4}$	$-\binom{1}{3}+\binom{4}{3}$
4	$-0.08\binom{4}{3}+0.08\binom{5}{3}+0.09\binom{3}{5}-0.09\binom{4}{5}$	$-\binom{3}{4}+\binom{5}{4}$
5	$-0.26\binom{6}{4}+0.26\binom{5}{4}-0.02\binom{7}{6}-0.10\binom{5}{6}+0.12\binom{4}{6}+0.08\binom{5}{7}-0.08\binom{6}{7}$	$-\binom{4}{5}+\binom{7}{5}$
7	$-0.01\binom{7}{5}+0.01\binom{8}{5}+0.22\binom{5}{8}-0.22\binom{7}{8}$	$-\binom{5}{7}+\binom{8}{7}$
8	$-0.13\binom{10}{7}+0.13\binom{8}{7}+0.02\binom{8}{10}-0.02\binom{7}{10}$	$-\binom{7}{8}+\binom{10}{8}$
10	$-0.08\binom{10}{8}+0.08\binom{11}{8}+0.07\binom{8}{11}-0.07\binom{10}{11}$	$-\binom{8}{10}+\binom{11}{10}$
11	$-0.12\binom{13}{10}+0.12\binom{11}{10}+0.04\binom{10}{13}+0.04\binom{11}{13}-0.08\binom{14}{13}+0.07\binom{11}{14}-0.07\binom{13}{14}$	$-\binom{10}{11}+\binom{14}{11}$
14	$-0.37\binom{14}{17}+0.37\binom{15}{11}+0.15\binom{11}{15}$	$-\binom{11}{14}$

d	$(\phi_h - \phi_d)' \times 100000\, \Delta \log \frac{d\,.\,.\,e}{c\,.\,.\,d}$	$a_1 (\lambda_h - \lambda_d)' \left[-\binom{c}{d} + \binom{e}{d}\right]$
1	$-0.0\binom{3}{2} +0.1\binom{1}{3} -0.1\binom{2}{3}$	$-9.5\binom{3}{1}$
3	$-2.7\binom{4}{1} +2.7\binom{3}{1} +1.0\binom{3}{4} -1.0\binom{1}{4}$	$+4.5\binom{1}{3} -4.5\binom{4}{3}$
4	$+0.6\binom{4}{3} -0.6\binom{5}{3} -0.7\binom{3}{5} +0.7\binom{4}{5}$	$+4.6\binom{3}{4} -4.6\binom{5}{4}$
5	$-2.7\binom{6}{4} +2.7\binom{5}{4} -0.2\binom{7}{6} -1.0\binom{5}{6} +1.2\binom{4}{6} +0.8\binom{5}{7} -0.8\binom{6}{7}$	$+1.0\binom{4}{5} -1.0\binom{7}{5}$
7	$+0.1\binom{7}{5} -0.1\binom{8}{5} -2.0\binom{5}{8} +2.0\binom{7}{8}$	$+0.7\binom{5}{7} -0.7\binom{8}{7}$
8	$-1.4\binom{10}{7} +1.4\binom{8}{7} +0.2\binom{8}{10} -0.2\binom{7}{10}$	$-3.4\binom{7}{8} +3.4\binom{10}{8}$
10	$+1.0\binom{10}{8} -1.0\binom{11}{8} -0.9\binom{8}{11} +0.9\binom{10}{11}$	$-3.0\binom{8}{10} +3.0\binom{11}{10}$
11	$-0.5\binom{13}{10} +0.5\binom{11}{10} +0.2\binom{10}{13} +0.2\binom{11}{13} -0.4\binom{14}{13} +0.3\binom{11}{14} -0.3\binom{13}{14}$	$-6.4\binom{10}{11} +6.4\binom{14}{11}$
14	$+5.4\binom{14}{11} -5.4\binom{15}{11} -2.2\binom{11}{15}$	$-7.6\binom{11}{14}$

d	$(\lambda_h - \lambda_d)' \times 100000\, \Delta \log \frac{d\,.\,.\,e}{c\,.\,.\,d}$	$a_2 (\phi_h - \phi_d)' \left[-\binom{c}{d} + \binom{e}{d}\right]$
1	$-1.8\binom{3}{2} +6.0\binom{1}{3} -6.0\binom{2}{3}$	$+0.2\binom{3}{1}$
3	$+4.5\binom{4}{1} -4.5\binom{3}{1} -1.7\binom{3}{4} +1.7\binom{1}{4}$	$+4.7\binom{1}{3} -4.7\binom{4}{3}$
4	$+2.3\binom{4}{3} -2.3\binom{5}{3} -2.6\binom{3}{5} +2.6\binom{4}{5}$	$-2.1\binom{3}{4} +2.1\binom{5}{4}$
5	$+1.6\binom{6}{4} -1.6\binom{5}{4} +0.1\binom{7}{6} +0.6\binom{5}{6} -0.8\binom{4}{6} -0.5\binom{5}{7} +0.5\binom{6}{7}$	$+2.9\binom{4}{5} -2.9\binom{7}{5}$
7	$+0.0\binom{7}{5} -0.0\binom{8}{5} -0.9\binom{5}{8} +0.9\binom{7}{8}$	$-2.5\binom{5}{7} +2.5\binom{8}{7}$
8	$-2.7\binom{10}{7} +2.7\binom{8}{7} +0.4\binom{8}{10} -0.4\binom{7}{10}$	$+3.1\binom{7}{8} -3.1\binom{10}{8}$
10	$-1.5\binom{10}{8} +1.5\binom{11}{8} +1.3\binom{8}{11} -1.3\binom{10}{11}$	$-3.5\binom{8}{10} +3.5\binom{11}{10}$
11	$-4.8\binom{13}{10} +4.8\binom{11}{10} +1.6\binom{10}{13} +1.6\binom{11}{13} -3.2\binom{14}{13} +2.8\binom{11}{14} -2.8\binom{13}{14}$	$+1.3\binom{10}{11} -1.3\binom{14}{11}$
14	$-17.7\binom{14}{11} +17.7\binom{15}{11} +7.2\binom{11}{15}$	$-4.1\binom{11}{14}$

Equation XXVII. $(\varphi.)$

$$
\begin{aligned}
0 = +6''.722 &- 0.0\binom{3}{2} + 4.6\binom{1}{3} - 0.1\binom{2}{3} - 2.7\binom{4}{1} - 6.8\binom{3}{1} + 5.6\binom{3}{4} \\
&- 1.0\binom{1}{4} - 3.9\binom{4}{3} - 0.6\binom{5}{3} - 0.7\binom{3}{5} + 1.7\binom{4}{5} - 2.7\binom{6}{4} \\
&- 1.9\binom{5}{4} - 0.2\binom{7}{6} - 1.0\binom{5}{6} + 1.2\binom{4}{6} + 1.5\binom{5}{7} - 0.8\binom{6}{7} \\
&- 0.9\binom{7}{5} - 0.1\binom{8}{5} - 2.0\binom{5}{8} - 1.4\binom{7}{8} - 1.4\binom{10}{7} + 0.7\binom{8}{7} \\
&- 2.8\binom{8}{10} - 0.2\binom{7}{10} + 4.4\binom{10}{8} - 1.0\binom{11}{8} - 0.9\binom{8}{11} - 5.5\binom{10}{11} \\
&- 0.5\binom{13}{10} + 3.5\binom{11}{10} + 0.2\binom{10}{13} + 0.2\binom{11}{13} - 0.4\binom{14}{13} - 7.3\binom{11}{14} \\
&- 0.3\binom{13}{14} + 11.8\binom{14}{11} - 5.4\binom{15}{11} - 2.2\binom{11}{15}
\end{aligned}
$$

Equation XXVIII. (λ.)

$$0 = +19''.938 - 1.8\binom{3}{2} + 10.7\binom{1}{3} - 6.0\binom{2}{3} + 4.5\binom{4}{1} - 4.3\binom{3}{1} - 3.8\binom{3}{4}$$
$$+ 1.7\binom{1}{4} - 2.4\binom{4}{3} - 2.3\binom{5}{3} - 2.6\binom{3}{5} + 5.5\binom{4}{5} + 1.6\binom{6}{4}$$
$$+ 0.5\binom{5}{4} + 0.1\binom{7}{6} + 0.6\binom{5}{6} - 0.8\binom{4}{6} - 3.0\binom{5}{7} + 0.5\binom{6}{7}$$
$$- 2.9\binom{7}{5} - 0.0\binom{8}{5} - 0.9\binom{5}{8} + 4.0\binom{7}{8} - 2.7\binom{10}{7} + 5.2\binom{8}{7}$$
$$- 3.1\binom{8}{10} - 0.4\binom{7}{10} - 4.6\binom{10}{8} + 1.5\binom{11}{8} + 1.3\binom{8}{11} + 0.0\binom{10}{11}$$
$$- 4.8\binom{13}{10} + 8.3\binom{11}{10} + 1.6\binom{10}{13} + 1.6\binom{11}{13} - 3.2\binom{14}{13} - 1.3\binom{11}{14}$$
$$- 2.8\binom{13}{14} - 19.0\binom{14}{11} + 17.7\binom{15}{11} + 7.2\binom{11}{15}$$

"The following may serve for an illustration of the general method of extinguishing side co-efficients:

$$\text{Eq. 1.} \quad 0 = 0 - \binom{2}{3} + \binom{1}{3} - \binom{3}{1} + \binom{3}{2}$$

$$\text{Eq. 2.} \quad 0 = 0 - \binom{1}{3} + \binom{4}{3} - \binom{3}{4} + \binom{1}{4} - \binom{4}{1} + \binom{3}{1}$$

"Let Eq. XXVIII$'$ = Eq. XXVIII + x Eq. 1 + y Eq. 2.

"The side co-efficient between Eq. 1 and Eq. XXVIII = + 19.2; and that between Eq. 2 and Eq. XXVIII = − 16.4. The diagonal co-efficient from Eq. 1 = $[a\,a] = +4$; that from Eq. 2 = $[b\,b] = +6$; and their side co-efficient = $[a\,b] = -2$. Hence, in order to extinguish their side co-efficients with Eq. XXVIII, we have

$$0 = +19.2 + 4x - 2y$$
$$0 = -16.4 - 2x + 6y$$

"Solving these equations, we obtain $x = -4.1$; $y = +1.4$. Hence the equations

$$0 = +4.1\binom{2}{3} - 4.1\binom{1}{3} + 4.1\binom{3}{1} - 4.1\binom{3}{2}$$

$$0 = -1.4\binom{1}{3} + 1.4\binom{4}{3} - 1.4\binom{3}{4} + 1.4\binom{1}{4} - 1.4\binom{4}{1} + 1.4\binom{3}{1}.$$

are to be added to Eq. XXVIII."

APPENDIX No. 18.

OBSERVATIONS ON CERTAIN HARBOR AND RIVER IMPROVEMENTS COLLECTED ON A VOYAGE FROM HONG-KONG, VIA SUEZ, TO NEW YORK, BY GEORGE DAVIDSON, ASSISTANT IN THE UNITED STATES COAST SURVEY.

NOTE.

The following paper resulted incidentally from the assignment of Prof. George Davidson, assistant in the United States Coast Survey, as chief astronomer of the party sent by our Government to observe the transit of Venus in December, 1874, at a station in Japan.

With the sanction of the Secretary of the Treasury and by his own consent, Mr. Davidson, in returning home, passed along the coasts of Asia and Europe, and examined incidentally the chief public works on the route, such more particularly as had been devised for promoting the interests of agriculture, or to further the purposes of commerce and navigation. His observations on some of the great structures for land reclamation and for irrigation have been printed by order of the United States Senate. The notes on harbor and river improvement which here follow were recorded during the same period, in conformity with the following items in the instructions which issued from the Coast Survey Office, addressed to Professor Davidson, in July, 1874:

"As the construction of breakwaters on the western coast of the United States is of growing importance while commerce increases, you will examine such works of that class as you can conveniently visit on your journey, and obtain such personal information and newly-published facts as may have bearing in the descriptions for prospective works of the kind.

"Examine the hydraulic conditions of the Suez Canal, especially at the Mediterranean end; note what changes, if any, have taken place, and the causes of change; also collect information in regard to littoral drift along the coast, and inquire particularly in reference to the progress of material accumulating on the west side of the great pier of Port Said."

In the United States practical interest, especially in what relates to facilities for commerce in transit from place to place and concerning the improvement and preservation of harbors and rivers, cannot lessen. The review on that subject, which follows, is therefore tendered in the belief that it is well to have the means for comparing our own condition on similar lines of advancement with the expedients found necessary, and which have been brought into requisition, in older nationalities.

C. P. PATTERSON,
Superintendent United States Coast Survey.

On certain harbor and river improvements in China, Egypt, Italy, Holland, and Great Britain.

The drawbacks are such in foreign ports that travelers journeying around the world will hardly find, after leaving the United States, a harbor where the ocean-steamship can at once go directly to a wharf or leave one, to disembark or embark passengers.

Leaving San Francisco from the wharf the steamship, after traversing the Pacific Ocean, is compelled to anchor off Yokohama, in the Bay of Yeddo; again, off Kobi, in the Inland Sea; and off Nagasaki, in the bay of the same name. But the American and some of the coasting steamers proceed directly to the wharf at Shanghai. Leaving there, however, by the English or French mail-steamers, passengers must find the vessel in the stream; they anchor in the Bay of Hong-Kong; go to the wharf at Singapore, and anchor at Penang, Point du Galle, off the surf-landing at Madras or any other coast port, and anchor in the Hoogly at Calcutta.

Again, at Bombay, at Suez, and even in the canal at Port Said, they do not go to the quay. The steamer anchors in the bay at Alexandria; so, also, in the Bay of Naples and at Trieste; and

by small boats only do passengers enter the ports thence eastward to Constantinople. Even in leaving England or Ireland the steamer must be boarded in the stream at Liverpool, or in the Cove of Cork at Queenstown, no matter how boisterous the weather. At New York, Philadelphia, or other American ports the steamer lands its passengers at the wharf under cover. And yet in many other respects the harbor improvements in most of the European ports are far superior to those in America. At Yokohama there are but limited improvements along the water-front, yet all of them have been built by the foreign community. Vessels lie in the bay, and all passengers and freight are landed and embarked by means of small boats and lighters. In typhoons, vessels are torn from their anchorages and much damage is done.

Nagasaki.—The harbor of Nagasaki is very fine, and capable of sheltering a moderately large fleet, except when typhoons blow from the southward. In January, 1875, the city had not recovered from the destructive effects of the typhoon of August, 1874. Vessels lie in the bay, and passengers and freight are landed and embarked by means of sampans and lighters. There is an excellent bund or quay on the east or city side, and several *hátobas* for landing and customs inspection. The principal and most commodious one is well up the eastern side of the bay, above the foreign settlement.

Shanghai.—The river is not very wide and the currents are moderately strong. There are quays along the left bank below the principal part of the foreign settlement, and quay-landings for the river-steamers higher up toward the native town. Shanghai has made considerable progress in the last twenty years, and the improvements along the river are creditable under the adverse circumstances which attend any progressive movements in that country.

Hong-Kong.—Vessels anchor in the roads, and passengers and freight are landed and embarked by boats and lighters. Quay accommodations for landing, &c., and for smaller vessels, and the steamers for Macao, Canton, &c.

Canton.—Up the Pearl River there are no improvements; the old forts remain as dismantled by the British men-of-war, and steamships of light draught go as high as Canton and anchor or moor in the stream abreast the upper part of the city.

Singapore has timber quays, where steamships land and embark passengers and freight.

Penang.—Vessels lie at anchor off the town. One modern quay for boats and lighters.

Calcutta.—Improvements in the river are such that vessels do not now anchor in Diamond Harbor, but proceed direct to Calcutta. Toward that city the banks of the river are protected where destructive action by the currents takes place. All vessels are moored in double or triple lines along the left bank, and landing and embarkation are effected by lighters. A great desideratum has been a bridge across the river above the city. The principal difficulty seems to be the want of good foundation, as the depth of diluvial deposit is very great. They have now a very large ponton-bridge for all ordinary traffic, but fears are expressed for its safety if any of the shipping should break away from its moorings during cyclones and be driven upon the bridge. Nevertheless, it appears quite feasible to protect it from such danger by powerful booms. The improvements in the drainage of Calcutta and its water-supply have been quite effective; and the death-rate is now almost as low as in the most favored European cities.

Bombay.—Vessels anchor in the bay, and are loaded and unloaded by a class of large boats peculiar to this region. The quays are of stone and very substantially built, but vessels do not come up to them. There are several large dry-docks, in which everything is constructed in the most substantial and enduring manner.

Suez and the Suez Canal.—The want of a good chart for courses through the Red Sea is a drawback to its secure navigation. The town of Suez, on the southern edge of the desert, which stretches thence to the Mediterranean Sea, is so low as to be not distinguishable until nearly up with it. Mount Altaka, however, on the west, is easily recognizable, having an elevation of 2,200 feet. It is a good landfall, and visible from the canal when well north of Kantara. Some of the harbor improvements of Suez can be seen from the usual anchorage. A long jetty of *pierre perdue* has been projected from the eastern shore just south of the entrance to the canal and crossing its prolongation. From the large and readily-distinguished deposit of sand on its southern face, it would appear as if there was a preponderance of littoral drift along that shore from the southward, and therefore its tendency is detrimental to the entrance of the canal.

Suez Canal.—We entered the canal at nearly low water, in a vessel of 1,267 tons burden, 276 feet in length, of 38 feet beam, and drawing 18½ feet forward and 19½ feet aft. Four men were at the wheel. The time of tide was nearly dead low water, and had fallen apparently three feet, but the current was still running strongly ebb. At this stage, the water was off the broad low slope of the upper section of the canal, and we could see not only the narrowness of the channel of deep water, but the condition and slope of the section beneath the water for ten or twelve feet. The course of the canal appeared more irregular than that laid down on the chart in hand, and from some cause or other the vessel's bow took the bank eight times within an hour and a half, and we advanced only a mile and a half in that time. Toward Suez, on the left, and to the north of it, the low tide had exposed the broad flats with narrow lines of water through them. The exposed banks showed thin strata of fine sand and clay alternating, but the clay predominating, so that the walls of the canal below low-water mark were without apparent slope. Where there is sand predominating on the surface of the upper flat section it appears to have been blown in. The stratification of the sand and clay affords capital natural material for preserving the integrity of the inferior sections. Where the action of the advancing waves, formed by the progressive displacement of the vessel, had fair opportunity to exhibit their destructive effects, the sand had mostly been washed away and the clay remained as a soft, sticky mud on the long slopes of the upper section. The channel near Suez and at the turns is too narrow, unless very skillful pilots and readily-managed vessels are used. Of course, the difficulty of steering is increased toward low water.

For ten miles of the first eighteen, from the entrance to the southern point of the Little Basin, the cutting above the surface of the water averaged but a few feet, and the surface sand appears to be very little moved by the winds, and even then to move parallel with the line of the canal. Certainly it is not a hundredth of the movement of the sand on the peninsula of California or at any other point on the California or Oregon coasts.

In the next twenty-three or twenty-four miles the line passes through the small and large basins called the Bitter Lake. For nine miles through the Grand Basin, between the two iron light-houses, there was needed no excavation, as the level of the bottom of the basin was below the bottom of the canal. It is asserted that since the admission and flow of water into and from the basin, the depth has increased on the line of the steamers, the bottom of salt having been carried away in solution. The light-houses are not used, as ships are not permitted to pass through the canal at night. Along the steamer's course through the lake are inexpensive iron angled tripods with iron disks at right angles on top, anchored and furnished with elaborate ladders to the top. Thence to the sixty-second mile the canal is through a moderate cutting, the highest spoil-bank being about fifteen to twenty feet above the surface of the canal. There are a few bushes upon the immediate banks of the canal, and occasionally some on the east side upon the spoil-bank. On the west slope, there is some slight sand-drifting. (See illustration No. 30, sketch 1.)

The distance through Lake Timsah is three miles, in a curve running well to the westward. Vessels do not stop at Ismaïlia, which lies on the northwest bank, upon ground about thirty feet above the lake. It is a pleasantly laid out town, with fine dwellings, large offices of the company, and a good hotel. The gardens are bright with tropical plants and trees, but they are wholly dependent upon the Nile water, which is brought by the Fresh-water Canal from Cairo. Just north of Lake Timsah, some bad turns in the canal are not fairly exhibited upon the map.

Then followed the deepest cutting seen on the whole canal; only, however, for a short distance of the six miles through fast land. Here* the cutting appears to be about thirty-five to forty feet deep, with spoil-banks of fifteen feet above them. (See illustration No. 30, sketch 2.)

The line of the old surface is well marked, so that no difficulty would be found in getting its exact height and breadth. The slope of the section of the spoil-banks is too great, being about one to one. On the west side there is evidently sand-drift from above, and the stairs on the west side, near the deepest cutting, are covered in places. Along the edge of the canal, bushes, reeds, &c., are sparsely growing in single line. These will prevent the washing away of the bank to some small extent, but cannot keep back the sand falling from above. The remedy should be applied above if at all practicable.

* Judged to be the 39th geographical mile-post from Port Said.

Even in this cut the signs are well marked of the fine clay and sand stratification; and the narrowness and slope of the surface section indicate that the least possible aggregate of material was removed.

With this high cut and apparently contracted section it is fortunate that the prevailing wind is nearly parallel with the line of the canal, which, however, has a direction, at this reach, of about ten degrees east of north, so that the west side is the one liable to encroachments from driving sand. But the adjacent desert is not wholly sand; in many places the surface appeared to be of heavier material that had been left during centuries in which the lighter material had been blown away. There were localities of sandy surface, and of course there is much sand to be blown from the spoil-banks themselves.

Lake Ballah is reached at about the seventieth mile from Suez, and thence the canal passes through the shallow lake and in its course for eleven miles it is cut through several low points and islets. Thence by a very low cut of two miles to Kantara, on the line of the old caravan-route from Cairo to Syria. Here the spoil-banks are already hard, and the sand so indurated in layers with the clay that pieces of it cannot readily be broken by the hand. It appeared to have chemical constituents, which, when acted upon by the air, were favorable to the solidification of the mass. At the water-line this was not the case, but above it there was little loose sand to be drifted.

From Kantara to Port Said the distance is 28 miles, or a total of 111 miles from Port Suez. In this last reach the canal was excavated beneath the surface of the water, but there is now no water visible on the east side of the canal, and the fast land stretches several hundred yards toward the westward; about half-way to Port Said this strip is three-quarters of a mile wide. And toward Kantara a mile or two of low, flat, rich alluvial soil borders the canal and needs only the water of irrigation to make it yield good crops. Along the last stretch of twenty-five miles the land slopes away so gradually from a low, narrow spoil-bank, that the question naturally suggests itself, where the excavated material has been placed.

Throughout this line the canal, as a rule, has apparently its full section, and the channel is marked on each side by a series of buoys, which have chains leading to the shore, so that their position can be changed. It is said that about the seventh or eighth mile from Said there is frequently a difficulty experienced in the channel shoaling, and the popular opinion is, that it arises from the bottom of the canal pressing in; but elsewhere reference will be made to another probable cause. There are one or two points of contraction of the canal section, notably between posts thirty-three and thirty-four, but the banks are hard indurated clay and steep to below water. At several points the spoil-bank is indurated and the sand is crawling in from the westward over it. In some places there are a few bushes, but evidently no persistent effort is made to cultivate them.

At the different stations, where the canal is widened so that vessels may pass, the piles at the landings are eaten by small worms upon the outside. No action of the teredo was observed, but destruction by the worm is great, as some of the new piers have the piles covered with zinc.

Destructive action by vessels passing through the canal.—All of one day was spent, and part of another, in passing through, at a rate of five and a half statute miles per hour. Apparently, a current was against the course of the vessel throughout, but was very slight toward Port Said. On this long line of low banks and full width of section, the action of the waves of displacement caused by steamers was marked and destructive. Parties were at work in laying low, dry, vertical walls. With large vessels, and especially of greater draught, the action must be much greater.

The small blocks of soft stone were brought down the canal by Nile boats. This was about all the repairs going on throughout the length of the canal. Two or three small dredges were at work, and one at Port Said; and one of the largest class was being put in working order just south of the port.

The extreme width of the canal at the surface of the water may be taken at 130 feet; it contracts to a width of 77 feet at 5 feet below the surface, so that its cross-section would represent about 1,750 feet. But this is not the cross-section in the heavier cuts, where the surface breadth is smaller.

The vessel in her progress continuously displaces a body of water, in the aggregate equal to

her own displacement; but the primary action of this displacing is forward of the midship section of the vessel, which acts as a piston in forcing a part of the water ahead. The rise of this part of the displaced water is not readily detected from the vessel, unless well-marked objects are on the line of water; at a point abaft the midship-section, about two-thirds the length of the vessel from the bow, there is a distinctly-marked rush of water aft on both sides the ship, from the higher level in front to the lower level aft, to supply in part the volume of displacement. The difference of level is very marked, and is of course more where the canal is contracted. From this higher level the water rushes strongly down and along the sides of the banks until it is met by a wave advancing astern the vessel, and following her to supply in part the volume of displacement. This wave rose from two to three or even four feet high from the lowest part of the trough, and, curling and breaking as it struck the bank, it did far more damage than the previous receding wave. Along the canal between Kantara and Port Said, where the section exhibits a broad band of shoal water under either bank, the destructive action of this wave was noted. There was a series of five descending and retreating and five of the ascending and returning waves, not reckoning the first wave in front of the vessel. From the first (or second, if we include the wave preceding the vessel) to the last wave the distance was about two hundred feet, or over two-thirds the ship's length. There is no difficulty whatever in deciding which wave is the most destructive; where the bank was sand, there would be a heavy washing away along the whole bank, except where the small vertical stone wall had been built; but even this was in many places washed down, doubtless by being undermined, and wherever the bank was fairly protected by rushes or by bushes, the destructive effect was very small.

In returning from Port Said to Ismaïlia in a small steamer sixty feet in length, similar effects were produced whenever she ran close under either bank; but when she was in mid-channel there was little or no damage done to the banks.

The destructive effect of the water disturbed by the screw may be regarded as nothing compared with that of the waves of displacement. These observations are noted in some detail, because they exhibit a constant and destructive agency at work far greater than the drifting of the sand by the wind, and in every case aiding it. They may be investigated by decreasing the speed of the steamers, which are now permitted to run ten kilometers (five and a half statute miles) per hour, whatever their size. Either a much smaller speed should be established or the speed made to depend upon the displacement; in which case the larger vessel would go through at a lower speed than the smaller vessel, and yet produce as injurious effects upon the banks.

Current through the canal; saltness of the water; tides.—The rise and fall of the tide at Suez is about three feet, and at Port Said about one foot, the latter depending in large measure upon the wind. And when the north wind blows very strongly down the Gulf of Suez and Red Sea continuously for a week, as it did upon our trip, the water is driven out quite sensibly. Fortunately, the basin of the Bitter Lake is a great reservoir to equalize the effects of the conflicting tides and currents. Nevertheless, there appeared to be a general movement to the southward, and as we approached the north end this was verified by the presence of the decayed vegetable matter from the Nile along the banks of the canal.

The littoral current along the shores of the Delta, or at least from the Damietta mouth across the mouth of the canal, toward the Gulf of Pelusa, is four kilometers per hour. The engineer of the company at Port Said gave reiterated assurances that such was the result of their observations. This current carries with it vast quantities of decaying vegetable matter from the Nile, and when the dredge was at work near Port Said, the excavated material contained abundance of large and small roots, branches, leaves, &c., and the odor was quite offensive. Along the canal-banks the line of the lighter decaying vegetable matter is well marked. On the return to Ismaïlia, and at every station, the same material was noticed for many miles within the canal.

At Port Said and off that mouth the presence of the fresh water from the Nile is very readily detected by the salinometer. The engineer of one of the Austrian Lloyds states that his numerous determinations of the quantity of salt in solution gave the following results with great uniformity: In the Red Sea, eight ounces of salt to the gallon of water; in the Suez Canal, eight and a half ounces; and at the Port Said mouth of the canal, seven and a half ounces. The increased salinity

of the canal is readily accounted for by the excessive evaporation going on, and by excess of salt from the bottom of the Bitter Lake, &c.

Breakwater at Port Said; dredging.—The western mole or breakwater at Port Said indicates that no violent storms occur in that locality. A few hours' action of the Pacific coast swell would spread that breakwater over the bottom of the sea. This west mole is a long line of béton blocks dropped at random, so as to form a pier with a cross-section, having the side slopes of 45°, with the top five meters in breadth and two meters above the sea. About one-third the way out upon the pier the water was washing through the wide interstices in many places, from the westward. Many blocks are broken across and irregularly; all are more or less worn, say two and a half inches deep, and exhibit sand and shells in the material as if from the beach. The wash of the sand through the wide interstices of the mole is so great that a dredger is constantly at work removing it. From the inner end of the pier the formation of the sand-beach, now about three feet above the water, has progressed outward six hundred yards, and is constantly working to seaward.

From the regular observations of the company, it appears that the western point of this formation is at the beach, three miles from the pier, and the eye plainly traces the line of disturbed water, with its load of Nile matter in suspension, from a point apparently half a mile off the beach in that direction to the extremity of the pier. The law of deposit seems regular, and already the pier has been prolonged, and will be farther carried seaward as the necessity arises.

The sand of this new beach, when dry, is drifted by the northwesterly winds into the canal, because there is no elevated line of bulk-head or fence continued landward on the line of the pier. This drift has formed so large a deposit within the canal that the mass above the water is gathered in heaps and sold as ballast to the outgoing coal-ships.

Although there was no dredger at work at the mouth of the canal, the engineer stated that the littoral drift carried th e Nile matter across the extremity of the pier and formed a bar, which is removed by dredging to thirty feet of water.

The material dredged from the canal is carried six miles eastward of the mouth and dropped into the sea. The machine observed at work takes up 1,430 cubic yards per day, and each steam-scow carries away 150 tons. The dredger at work was bringing up only two-thirds of the buckets full of material. The eastern pier is not parallel with the western, nor is it so long. It appears even of less dimensions than the other, and there is no intention to increase its length or size. So far as can be judged from the present effects of the littoral drift, and from the prevailing moderate northwest winds, there is no absolute necessity for this eastern mole.

Béton blocks; manufacture; character; size; cost.—The engineer of Port Said attended at a visit to the Béton Works, which are on the east side of the canal, nearly opposite Port Said. The sand and cement are incorporated in a series of large iron arastras, each with four iron wheels for thoroughly mixing the material. Power is transmitted by shafting from steam-engines under a large shed. When the sand and cement are sufficiently incorporated, two closed rectangular openings in the bottom of each arastra are opened, and the contents are dropped into a wooden box about four feet square by two feet deep, placed on a truck, which is moved about twenty or thirty feet to a position where its contents are deposited in the mould. This mould is on wheels, and moves by rail parallel with the series of arastras, so that it may be moved under each of the boxes and receive their contents, until the required amount is in the mould. The blocks, when a little worn, show lines separating the layers, and these appear to be about ten inches thick. The béton blocks contain 353 cubic feet and weigh 20 tons. They are a little more than 10 by 6½ feet in length and breadth, and 5 feet thick. The material "sets" at once, and then the blocks are parked ready for use. When they are needed a large iron bridge on two sets of rails is run over the block, which is hoisted in slings by hydraulic power on the bridge, and then moved to another rail at right angles, on which runs a heavy truck. When this truck is loaded it is moved to the shipping-point, where similar hydraulic power on a second iron bridge lifts it and deposits it on the vessel. At first, these blocks were made out of beach-sand, &c., but they were found to disintegrate badly, and now the company obtains the sand from Kantara, because it contains so great a percentage of silica, and no salt. As elsewhere mentioned, the sand excavated from the canal at Kantara had become hardened in the spoil-banks by simple exposure.

These béton blocks cost 340 francs each ($63.75) when laid on the mole. Up to May 12, 1875, the company had made 13,000, and had a stock remaining on hand. The total cost of the two piers at this rate would therefore be $828,750.

The light-house, near the inner end of the western mole, a graceful octagonal structure about one hundred feet high, is built of béton of the natural color, and is surmounted by an electric light, on a range for entering the canal between two moored lights in the canal. The light-house buildings are surrounded by a béton wall.

CONCLUSIONS.

Estimate of cost.

As a great artery of commerce, the canal is a success. The largest class of steamships and men-of-war pass through it; on an average, seven vessels are *in transitu* at one time. It has given rise to new forms of vessels resembling enormous canal-boats, and known to the profession as "canallers." Financially, no opinion is here intended upon the subject, but so far as could be learned, the tonnage transit duties average $375,000 per month. As an engineering work, and putting aside unknown questions of diplomacy and finance, there have been no extraordinary difficulties to overcome. The question of route was within very narrow limits, and the surveys necessary for determining the most feasible line could not admit of doubt in the location. The southern part, from the Bitter Lake to Suez, follows the line of canal of the Pharaohs, and does not diverge much from it to Lake Timsah. The northern terminus may or may not be in exactly the best location. The direction of the littoral drift would greatly affect that question.

The material through which the canal has been carried is of a very favorable character, for facility of removal, formation of spoil-banks, and the preservation of the section.

Alexandria.—The new breakwater protects the harbor from all winds from the northward and eastward. It is constructed of "*pierre perdue*" apparently without, with a sufficient section to withstand such seas as arise here. But the efficiency of the whole harbor is reduced by the old mole which runs out northward from the southern shore of the harbor, and gives an area much too limited for the present demands. This mole stretches so far toward the north shore of the harbor as to cramp the passage between them for long vessels. The new mole, if projected farther to the northward, would have given a larger area for the harbor. If heavy seas should ever attack the mole, it is, perhaps, too high to withstand them. The bottom was of yielding material, as might readily be supposed.

Naples; Genoa.—Nothing need be said of the former, with its small mole. At Genoa, the new great breakwater affords a good anchorage for a large body of shipping in deep water; but the vessels principally crowd inside the inner or old mole, and are moored in tiers very close together. Passengers and freight are landed and disembarked by small boats and lighters. Large vessels also lie moored under the shore hence to the light-house, which is situated at the inner end of the outer breakwater. The breakwater is finished with masonry on the top and inside, and when visited there was a very strong breeze and moderately large swell rolling in, which threw its spray over the breakwater. From the light-house a view was obtained of the new and old breakwaters, and of the coast-line to the east and westward. The new mole might have been located farther out, with its western end anchored upon the extremity of the promontory upon which the light-house is built. The light-house is a plain substantial structure of stone upon a rock, and perhaps not less than three hundred feet above the sea. The light is of the first order of Fresnel.

Swinemunde; breakwaters; improvements in channel.—Stettin lies on the Oder, thirty miles south of Swinemunde, with which it has water communication for vessels drawing sixteen feet. The line of steamers that had been running for a short period thence to New York was withdrawn on account of a lack of patronage. The Oder at Stettin is quite narrow; nevertheless, it admits of a large Baltic trade. The stream in many of its characteristics bears a strong resemblance to the larger bayous of Texas, especially toward its mouth, which opens not directly upon the Baltic, but into the Stettiner Haff, a fresh-water sound about seventy-five miles in circumference, and bearing much the same relation to the coast-line as Pamplico and Albemarle

Sounds bear to the coast of North Carolina. This body of water is divided into the Grasses Haff on the east and the Kleines Haff on the west; and the water of the Oder and of other streams finds three passages hence to the Baltic, by the Dienow at the eastern extremity, the Swine in the middle, and the Pune on the west; the sound mouths of the extreme passages are thirty miles apart, and their courses are long, but the course of the Swine is only about twelve miles.

Swinemunde lies directly upon the Baltic, on the left bank of the Swine, and is a modern sea-port, where heavy and deeply laden vessels for Stettin receive and discharge their cargoes. For the desired examinations, kind and prompt assistance was rendered by Mr. Pantel, the United States consular agent.

The improvement in the depth of the narrow entrance, by artificial means, is very noteworthy. Formerly, the entrance to the channel was protected by short moles constructed of blocks of stone thrown upon a base-work of fascines. These were destroyed by the gales of every heavy winter. The depth of water on the bar was then (1828) six feet, and there is no rise and fall of tide except what may be occasioned by the prevalence of strong winds, which, in northeast storms, bank the water over the streets of Swinemunde. But there is a constant current out from the Stettiner Sound, which is mainly supplied with fresh water from the rivers Oder, Ihna, and Ucker; but the current here is not strong on account of the other outlets already mentioned. The narrowest part of the artificial passage is 350 yards, but this does not represent the channel-way, which is not quite half that width between the 24-foot curves. As nearly one-half of the western side of the passage has less than six feet of water, it is intended to construct a new bulwark over the shoal line, and thus contract and doubtless improve the artificial channel. Within the 24-foot lines, two ocean-steamers can pass each other without difficulty. The artificial channel is formed of two nearly parallel moles of unequal length, running out, not in a straight line, but curving well to the westward. In fact, the outer or eastern mole, and the shore-line inside, is 115 degrees of a circle having only 2,000 yards radius; and for two miles the deep water scours directly under its wall. The mouth of the channel is thus caused to open to the northwest by north (true), and vessels running for refuge, in northeast storms, must run under all sail for the extremity of the pier, round it within a ship's length, and haul up sharp on a southeast by south course, or go upon the western point of sands and be lost. Last winter there were four vessels lost by not conforming to these requirements; one losing all hands, because neither the tug nor life-boat could reach her. From the East Fort on the right bank the distance to the light-house on the extremity of the east pier is 2,600 yards, of which the outer two-thirds is the recent stone pier extending from the present beach-line. The extremity of the western pier (built in the same manner, but without parapet) is 600 yards inside the eastern pier, but the line of shoal water extends on the line of its prolongation far beyond the extremity of the eastern pier.

The section of the eastern or principal pier is fairly illustrated by the accompanying sketch (illustration No. 30, sketch 3). It has to withstand the heavy northeast gales, is quite small, and very low; but the blocks of stone are laid securely in cement. The swell broke completely over it in winter, and it was decided to build the five and a half foot parapet all along the pier, on the seaward face. Notwithstanding the masonry of this wall was very good, its section proved too small, for the gales of 1874–'75 carried 250 feet of it bodily into the channel. The piers have been prolonged several times as the deposits have taken place off the beach, which was formerly inside the present brick forts. The beach has, therefore, made not less than 1,050 yards to seaward; and the indications from the soundings are that it is merely a question of time when additional length shall be given to the piers. A study of this case indicates that the prolongation of the west pier is not necessary, but that the prolongation of the east pier may be necessary, and should be carried out in a straight line, or rather in a curve of gradually-increasing radius. What littoral drift there is seems to prevail from the eastward, and the deposit on the prolongation of the west pier is partly from the sound and partly from the littoral drift. But the increased depth of water in the channel is not wholly due to the piers, but in part to the constant use of a small dredger. The cost of maintenance of the piers and of the dredger is quite moderate, and the results are the most favorable as yet seen upon a coast subject to very heavy gales.

Copenhagen.—There are no recent harbor improvements here, and nothing requiring special notice.

Kiel; German naval dock-yard on the Baltic.—Misistohe, the great German naval dock-yard of the Baltic. It is at the southwestern extremity of Kieler Bay, opposite the town of Kiel, and between the villages Wilhelminenhohe and Ellerbeck. The approaches along each shore of the bay show rolling land of slight elevation, cultivated and dotted with houses and villages. The defenses are good and have been much enlarged and strengthened.

The extent of the dock-yard is about 1,160 yards frontage by 660 yards in depth, giving an area of about 160 acres. The greater part of this area was not only solid ground, but the hills to the eastward have been cut down 95 feet to bring them to the level of the works. There are to be two large basins for construction, repairs, and outfitting. The outer one is 315 yards by 242, with an entrance 133 yards wide and 210 yards long.* This dock is to be connected with the inner one, or building-basin of 240 yards square, by means of a passage 25 yards wide and 68 yards long. At the farther side of this basin are four large graving-docks, the largest of which is 260 yards long.

Then come the extensive establishments necessary for a first-class dock-yard, but of which hardly a commencement has been made. The graving-docks have inverted arch bottoms and solid brick walls between each other. The foundation for the walls is good gravel, and requires no piling, although sheet-piling was being driven for the sides of the cross-walls between the two large basins. These walls are 15 feet thick. Over the gravel is laid béton to give a level continuous surface for the wall, which is coped with stone. The bricks used are slightly larger than American bricks; yellow, very hard, well burned, and, when struck, emit a metallic ring. They are brought twenty-five miles by water.

Hamburg; docks.—No noteworthy improvements. One or two small dredgers were noticed in the river between Hamburg and Blankenese. The right bank of the river is a bluff about sixty feet in elevation; the left bank low, and the country between the north and south branches of the Elbe is flat, low, swampy, and cut up by many broad sloughs. When there is any tendency to cut away the right bank, frequent narrow, low lines of stakes and stones are carried out at right angles to the beach for twenty to thirty-five yards, and they appear to be sufficient. The vessels along the main quay of Hamburg are arranged in tiers of two and three deep, with passages for barges to load and unload. These barges receive and discharge freight at cranes along the quay-front, or at the warehouses on the numerous canals running through the city. In the latter case, there is no pavement bordering the canal. The "Sandthorhafen" had only large steamers, principally English, loaded with coal. There is a great line of brick sheds with iron roofs down each wharf, with the fronts toward the water open; but on the outer or street side they are closed with great doors. Between each line of sheds and the dock there are laid two lines of rails; the outer quite broad for carrying movable steam-cranes, the inner one, of the ordinary breadth, for cars; but apparently none are used, as the freight is discharged by the cranes directly into the shed, and thence it is shipped into the cars on the outside of the shed, where there are four lines of track between it and the street, which is railed off by an iron-wire fence.

Bremerhafen; old and new docks.—There being nothing of interest at Bremen, the route was continued to Bremerhafen, to examine the great docks already built and those in progress.

There are two docks at Gestemunde opening into the small stream Geste, where it debouches into the Weser with a rapid current on the ebb-tide. Below the Geste are the two finished docks of Bremerhafen, and the third one under construction. These are all on land subject to overflow at high water, but diked in with the material excavated. The soil is a stiff blue clay sixty feet thick over sand and gravel. Piles are driven sixty feet, or until they penetrate two feet into the gravel, when they can be driven no farther. Over the piling is laid a grillage, and upon that the walls of brick are laid in cement. The bricks are red and good, but not equal to those at Kiel. The walls are coped with stone. The depth of water over the sills of the docks is twenty-seven feet; and there are two sets of gates at each entrance; the outer one is the higher, to keep out flood-waters. The docks of Bremerhafen open up stream, but those of Gestemunde open into the Geste. This arrangement of the lower docks is made because the vessels enter at three-quarters flood, and the

* These numbers are taken by scale from a plan of the docks.

pilots can therefore better handle the vessel against the current. But this form is particularly favorable for the deposit of silt, especially as the river brings down a very large amount of material in suspension. The deposit in the entrance is two inches each tide, or four inches daily; of course, there is not so much inside the gates, as they are only open one and a half hours before high water and for a short time after. This deposit is removed every eight days, when it has reached a depth of two to three feet, by scouring. When the water on the outside is six feet below the surface of the water in the docks, the inner gates are opened, and the scour cleans the entrance, which is a smooth flooring of masonry laid over grillage and piling.

In winter, the ice forms to an aggregate thickness of six feet, and is kept broken in the docks by small steamers plying constantly. When it becomes too heavy it is carried out in the same manner as for scouring the entrance. Mr. Ihlder, the United States consular agent, states that the river-ice has not damaged the pier-heads (of timber) at the entrance to the docks, but what seems to be a local eddy is noticeable in that vicinity, that sweeps the ice away from the diking and the piers; otherwise, they would offer a constant obstruction to it. This, however, instead of an eddy, may be the outpouring ebb-waters of the Geste, opening at right angles to the river just above the first or upper dock, which throws the ice off the immediate shore-line. The Weser does not become frozen fast in winter at Bremerhafen, but about two miles above Gestemunde it does, and thence there is sleighing on the river to Bremen. Bremerhafen is a great *entrepôt* for petroleum, and vast sheds are stored with it beyond the third or lower dock. In the second dock, sixteen of the large steamers of the Bremen Line were laid up on account of depression in commerce.

Wilhelmshafen; German naval dock-yard.—This is the new German naval dock-yard upon the North Sea. It is neither so extensive nor so important as that at Kiel. The site is on the reclaimed land near the village of Heppens, on the west point at the narrowest part of the Jade Bay. The inner harbor is 400 yards by 240, and has three dry-docks and two slips for the construction and repair of iron-clads. This harbor is 700 yards from the extreme point of entrance; and the canal and receiving-harbor are executed in heavy granite masonry. In the entrance-harbor was lying a dredger, evidently needed to keep the required depth in the approaches. Additional reclamation is being made to give more dockage on the southwest side of the entrance. The soil is a stiff black clay, and is used for forming the dikes without the use of fascinage or other helps. The railroad connects Wilhelmshafen, which is quite a pleasant place, with Oldenburg; and a large canal is being opened close under the embankment.

The Amsterdam Canal; enlargement; protection of banks; North Sea Harbor; dredging; breakwaters.—There are already two or more printed descriptions of the details of this work, so that reference here need be made only to some of the changes deemed necessary, and to the points that more especially attract attention. The canal west of Velsen and the North Sea Harbor were visited with Mr. Dutton, the executive engineer for the contractors Of the party were also Messrs. Waldrop, Rose, and Siemens. From Mr. Dirks, the chief engineer, copies were received of all the specifications of the work, and the maps exhibiting the lands reclaimed, &c.

The sand-dunes, bordering the coast-line for an average breadth of two miles, are about forty-five feet above the sea; and from Velsen westward the heaviest and only cutting of importance has been effected. These dunes are not naturally covered with vegetation. The cut through these dunes was finished 203 feet wide at the surface of the water; but as new projects for a great central railroad-station were commenced at Amsterdam, and the city needed material for filling, it granted a subsidy of $2,400,000 to the Canal Company for sand, upon the condition that the surface width of the canal should be increased to 230 feet; the depth to be 27 feet for a bottom width of 115 feet, giving a slope of one to one for the sides. This widening is now in progress along the south side of the canal.

To protect the banks against the destructive effect of the wave of displacement of the steamers, they will be pitched below and above the surface of the water with blocks of one, two, or three cubic feet dimensions, of hard limestone, or of basalt from the Rhine. They will not be smooth laid; the idea is that rough pitching will break the wave and retard it; but unless the stone is deep, the sand will probably be washed from between and from below the stones, as may be seen at some parts of the newly-made wall on the Suez Canal. At present, the protection is a

wooden bulk-head, which is about two feet above the surface of the water. Engineer Waldrop says the best defense is a reed, that is indigenous. Near Amsterdam it was observed that a fringe, four feet wide, of this reed, five feet high, completely smoothed the top of the principal advancing wave, which had been combing and tearing along that part of the bank of one of the canals protected by stone. Among the reeds the wave was as high as along the sloping stone wall, but it had little or no bank-destroying power. The reed was then (August 27) nearly in seed, and looked like a carex. It is not, however, propagated for this work by seed, but transplanted, and in a sandy soil, on the edge of the canal, is put 18 inches deep, in a muddy soil about 10 inches. It would be even better than the tule of California, because it grows much like a tall, coarse grass or millet, with a stalk half an inch in diameter, and with many leaves. Along the canal, through the dunes, these reeds are planted inside the present wooden bulk-head. The dunes for a good distance on each side of the canal, and the slopes of the canal, are planted with a coarse grass, $2\frac{1}{2}$ feet high, which grows well, and effectually protects the sand from drifting. It will grow from the seed, but in that case the sand may be driven away, and leave the seed exposed. The transplanting costs one cent per square yard, and the growth is thick from fallen seed. From this thick matting, the plants are taken for transplanting. It seeds at the end of August. The slopes of the canal-banks above the water are one to one and a half, and this grass holds them perfectly. It would be a capital covering for the sand-dunes of California and Oregon. It is locally known as the *trelm.*

The dredger, costing from \$15,000 to \$17,000, places in the scows an average of between 700 and 800 tons of material daily; but 1,500 have been removed in one day. Each scow carries from 100 to 110 tons, and is towed seaward to 15 fathoms of water and discharged. The means of closing the six shutters of each scow, so that each shall have the same strain to keep it closed, is quite simple and ingenious, and very effective. Inside the canal the small dredgers, of the ordinary scoop form, were removing only 400 tons daily; but the dredgers are quite small. The sand is raised to the top of the south bank, and carried hence by tram-way to Amsterdam.

The depth of water now (August 27, 1875) in the canal is reported at 16 feet, and the company are under contract to have that depth through the harbor and the canal by April, 1876; to be increased to 27 feet (8 meters) throughout by 1877.

The entrance locks and sluices.—The two locks and the sluices near the seaward entrance to the canal are simple, fine-looking pieces of brick-work, without the least indication of cracking or settling. The longest lock will receive a vessel of the largest class. It has three gates (for protection) built of iron, with air-chambers, and is balanced so as just to be buoyant. The first gate, toward the sea, is the strongest and highest, as a guard against storm-floods, and weighs 57 tons. The middle one is lower, and weighs 45 tons. The inner is the lowest, and weighs 33 tons. The brick walls separating the locks decrease in height with the gates. These piers are built upon a grillage, resting on piles, and no difficulty was experienced with the side piers; but some trouble was encountered with the central one, where a stream of 10 inches had to be led off until the work was nearly done, when it was closed up without difficulty. The bottom of the lock-chambers and the aprons, and the bottom of the side channels, consist of fascinage, broken bricks, and basalt-rock pitching.

The béton blocks.—It is claimed that the béton works are the most extensive in the world. The concrete is composed of sand, shingle, and cement, in proportions specified in the contracts. The sand here does not make good béton, so it is brought a distance of 100 miles. The blocks range from 4 to 10 tons, with sizes $3\frac{1}{2}$ feet thick, 4 feet wide, and from 5 to 13 feet in length. At the contractor's office it was intimated that they had been found too small, especially along the exposed faces of the piers, where the heavy waves tended to lift them up. It was in contemplation to increase the size of some of them to 20 tons. When brought from Velsen, they are first stored on the north side of the canal near the shore. Subsequently, they are carried by rail across a wooden trestle-work to the inner end of the south pier, where they lie until needed. Thence they are moved on a tram-way laid on a pier, in pairs, and stored near the outer end until needed, when they are lifted by the crane and placed *in situ.*

North Sea harbor breakwaters; design; method of building.—While landing on the inner side of the south breakwater or pier, a swell was running square on the line of the pier, from the

effects of the last gale. The work is out to 4,723 feet (1,440 meters), and the foreman stated that he was working in 36 feet of water (11 meters); although the piers are intended to go out to only 27 feet (8 meters). The experience gained in the construction of these piers is valuable. The original design appears to have been somewhat similar, if not identical, with that of the Admiralty pier at Dover. This consists, at the inshore end, of a solid sea-wall (having a hearting of concrete) with a slight batter on each side, but changing to nearly vertical sides as it progresses outward, and abandoning the hearting of concrete. This (the Dover) pier rests upon the hard, chalky bottom which is not torn away by storms; but the case is wholly different at the North Sea Harbor, where the bottom is coarse sand liable to shift, and very quickly carried away when any large body is placed upon it, around which irregular currents are generated. Therefore, when this Dover plan was adopted here, the sand was washed away from the base of the breakwater, which by its weight again pressed out the sand beneath it; and this was in turn washed away, so that the pier settled and gave way. Without abandoning this method, the lowest layer of béton blocks was allowed to settle until it was embedded in the sand; it settled irregularly, but was leveled off near the low-water line to serve as a foundation for the upper courses. This was necessarily slow and expensive, and it is doubtful whether it was not, in great measure, liable to subsequent underwashing in great storms. Then two outer and boundary lines of concrete blocks were laid with the interspace filled with basalt blocks; *a pierre perdue* as a foundation. But it is evident that the process of undermining the marginal blocks is identical with that attacking the pier itself, and then the loose basaltic foundation must yield.

After abandoning this, a base has been formed by throwing in basaltic and limestone rocks upon the sand to the depth of one meter, for a breadth of 33 feet on each side of the base of the breakwater; beyond that, they take the natural slope. These rocks are approximately leveled by a diver, who then spreads a layer of spall (of pieces 6 by 2 inches, or thereabouts) so as to fill the interstices of the larger blocks. The leveling of this riprap is done by means of an iron bar swung horizontally from the end of the crane by a double chain. The béton block is then lowered to its position over this leveled part, and trial made of its horizontality by means of an iron disk, 15 inches in diameter, suspended by a chain from the crane. This disk is moved over different parts of the block until the required accuracy is attained. The work is quite tedious, because the seeing is always difficult on account of the discolored water.

After the lower blocks are laid, basaltic blocks similar to those of the foundation are laid along each side of the breakwater to the top of the first course. It is found that there is a heavy scour at the end of the breakwater as it is being carried out, so that the foundation-bed of riprap is really placed on a depression of 3 or 4 feet, if not more, thereby giving some advantage to the foundation.

Some of the ablest Dutch engineers express grave doubts about the foundation of the breakwaters, and insist that it should have been made of fascinage. The béton blocks are carried up to the low-water line without cement; and it is found that the blocks are, at that height, generally level, as required by specification. For the joints at the low-water line a quick-setting hydraulic cement is used; above that, Portland cement. In examining the whole length of the pier, the surface was found to be irregular and apparently sunk in places, and cracked across quite frequently. In fact the first crack across was within 20 or 30 yards of the pier end, and was continued below the water-line. The general appearance of the pier is unfavorably light and not of superior material; 2½-inch iron rods had been laid in grooves of the upper end outer course of blocks about 2½ feet from the seaward edge, and then covered with concrete; but frequently the concrete was gone, and the rods exposed and badly oxidized. The damage, or danger of dislocation or fracture of the outer blocks, increases toward the shore end, and cross iron tie-rods, round and square, have been introduced to meet emergencies caused by fracture. The introduction of this cramping is a new article in specification No. 5 *g*, being the seventh modification of the original plan, August 6, 1873.

The surface blocks are badly weathered. About half the way out to the breakwater a continuous concrete parapet wall has been built along the south edge of the south pier. It is about 5½ feet high and 6 feet wide; but the material is already badly worn, and in places is broken through. No examination was made at the north pier, but specification No. 5 *g* says that both breakwaters

shall be similar in construction. It will be recollected that an attempt was made to construct this north pier by commencing seaward and working toward the beach, and that the plan failed on account of the scouring away of the bottom from around and under the pier, and between it and the shore. This scouring process was so destructive that it endangered and finally carried away the scaffolding for the rails, by washing away the sand from around the screw-piles. The breakwaters are each to be 5,058 feet in length, and at the extremities the breadth of the top of the north pier will be 27½ feet (8.35 meters), and that of the south pier 26½ feet (8.05 meters).

The dredging of the North Sea Harbor, formed by these two breakwaters, will be completed by the first of April, 1876, to give the following bottom widths and depths along the center line of the harbor:

At the entrance, 284 yards wide; 26½ feet water at low tide:
At 550 yards inside the entrance, 909 yards wide; 24¾ feet water at low tide:
At 1,090 yards inside the entrance, 305 yards wide; 23¼ feet water at low tide:
At 1,210 yards inside the entrance, 82 yards wide; 23 feet water at low tide:

and thence the same depth through the canal to Amsterdam.

As already mentioned, it was originally intended to carry out the breakwater as a solid wall, but in addition to all the modifications which have been specified, it has been found necessary to protect it by a line of béton blocks thrown in *a pierre perdue* along the south or seaward face of the south pier to the level of the water, in order to break the force of the southwest swell upon the wall, and probably to protect the base. But it seems not altogether improbable that in very violent gales the southwest seas may drive these loose blocks against the wall and parapet to their injury. Specification No. 39, of April 25, 1875, prescribes that these "wave-breakers" shall be carried for certain named distances along the sea-face of each pier, and around the pier-heads to the inner facing. The cross-section of this loose material is fourteen feet on top, at ten feet above low water, with the outer slope of one to one; and the material comprises 162,000 cubic yards of concrete and basalt blocks, the latter being in comparatively small masses, and some of the former condemned material.

The tides rise 4 feet, and it is said that by a peculiarity of the tides meeting here, littoral drift is prevented; but in the green water a well-marked line of current rips was noticed, which indicated a current then setting to the northward, while the discolored water was only half a mile out from the south pier, but spread out much farther to the northward of the harbor. That may have been on account of the previous day's strong southwesterly wind, which raised sufficient swell to prevent the laying of any blocks.

Dam at Schellingwoonde; the eastern extremity of the Amsterdam Canal; difficulties of construction; how overcome.—A description of the work of the Amsterdam Canal and the North Sea breakwaters would be incomplete without reference to the dam across the Ij (or Y) at Schellingwonde, near Amsterdam, although it comes partly within the subject of land-reclamation.

When the Great North Sea Canal (the Amsterdam Canal) was originally proposed there was a multitude of objections to it, among which was the liability of the canal to fluctuations of water-level from storm-changes in the level of the Zuyder Zee. Then also it was demanded that the adjacent waters of the Wijkermeer and the Ij, which are the southwesterly termination or arm of the Zuyder Zee, should be drained in order to make the undertaking commercially (financially) successful. But after some years of waiting and discussion this project was considered essentially a part of the scheme. To overcome the first objection it was decided to dam the Ij just east of Amsterdam, and between Schellingwonde on the north side, and Paardenhoek, near Leeburg, on the south. The hostility to this essential feature of the great idea was eventually overcome, and this remarkable dam was constructed under unusual difficulties.

The dam or embankment is 1,482 yards in length, and is built upon fascinage in depths from 5 to 25 feet, upon a bottom of soft mud about 40 feet deep, resting upon sand. The usual rise and fall of the tide is 14 inches, but storm-tides reach 10 to 15 feet, at which times the current through this channel-way is two and a half miles per hour. The breadth of the base of the dam is 140 feet, except the closing part which is about 150. The assumed settlement of the center line of the dam was 13 to 14 feet, and the line of the crown is 15 feet above ordinary low water.

The first operation in building the dam was to cover the entire site with a strong fascine-mattress, worked in pieces of 200 feet in length, 30 inches thick, and overlapping each other about 3 feet. Then upon each edge of this floor-mattress, long narrow mattresses, at first 25 feet broad, are laid at low water, each superior mattress being narrower, and receding from the lower edges of the one below, so as to give a sharp slope on both sides of these parallel lines of marginal mattresses. These are brought up to high water. Between these rows of fascine-work the space is filled with sand and clay, resting upon the floor-mattress. As the work sinks in the soft mud, the marginal fascinage is added and the sand and clay filled in. Above the high-water line, the proper cross-section is given to the work both with fascines and filling. The details of the manufacturing of these mattresses and other fascinage are not necessary.* The substratum of mattresses, when loaded, sinks in soft mud with moderate regularity and gradually, unless the mattress is weak, and becomes ruptured lengthwise, as happened in the Schellingwonde dam. In this case, the mattress split longitudinally, and the halves separated. The only remedy was to fill the cavity with clay and sand until the settling ceased. It was originally intended to use a double-floor mattress, but the plan was abandoned, lest water should penetrate the dam through such a thickness of fascinage. In sandy soil there is little or no danger of this, as in a few days the sand finds its way in the interstices of the fascinage and makes a solid mass of the whole. But it would appear reasonable to suppose that when the floor-mattress was laid in this case, a thin layer of sand might have worked sufficiently through it, and then a second mattress over this might have been similarly treated; or they might have been separated by several feet of sand and clay, and thus have given a strong fascinage flooring that would necessarily have sunk, but would not have been ruptured. There is one great advantage in the use of fascines in such an undertaking, and that is in closing the water-way. In the Schellingwonde dam the opening was 328 feet, and this was closed over the whole width simultaneously; but of course the small rise and fall of tide and weak current were favorable circumstances. The principal difficulty in the construction of this dam was in building the foundations for the sluices and locks near the north side, now called the "Orange sluices." The north wing at the dam stretches three hundred and twenty-eight yards from the Schellingwonde side; and then the abutments for both sides of the sluices, the drainage-sluices for the pumps, the three locks for navigation, and the outlet-sluice occupy 136 yards. For the construction of these sluices and abutments an immense coffer-dam, 175 yards in diameter, was made of two concentric rows of heavy sheet-piling, each pile being from 75 to 80 feet in length. It was unsuccessful; various failures were overcome, and it required three years before the work was completed. The masonry works rest upon grillage laid upon a forest of 9,000 piles, averaging 75 feet in length, and which have been driven into the sand. Memoranda concerning the pumps, &c., will be found under the head of land-reclamation.

Cherbourg; commercial and naval docks; breakwater.—This artificial harbor was visited under letter from "le Ministre Secrétaire de la Marine et des Colonies." The entrance-dock and the commercial dock at the mouth of the small stream on the east front of the town showed good masonry, in large blocks of granite, with no signs of settling or breaking joints. The docks are badly silted. The large naval docks, workshops, magazines, and arsenals are well constructed. The docks were, in part, cut out of the rock, and have been walled with granite. Apart from this fine naval dock-yard, which has an extreme length of 2,000 yards and an average breadth of 850, the principal object is the great breakwater, which stretches across the roads about 2,000 yards north of the dock-yard, but 3,300 yards north of the piers at the entrance to the commercial dock. This breakwater is laid in water from 33 to 46 feet in depth, with a good passage at either extremity. The western passage is 2,500 yards in width, and the eastern passage is 1,050. The length of the breakwater is 4,120 yards, or two and one-third miles. It protects the anchorage from all winds coming from the northwest to the northeast, and a large fleet may lie under it in safety. The construction was commenced about 1784, by placing large wooden caissons, filled with rocks, on the line of the breakwater. This was found to be unsatisfactory, too expensive, and too slow; and after four or five years the system of a breakwater made of riprap, or "*en pierres perdues*," was adopted. This appeared to have been successful, especially when coped with a thin line of masonry; but in February, 1808, during a heavy tempest, one part of the breakwater, upon which was the "Batterie

* See Watson "On the use of fascines in the public works of Holland."

Napoléon," was torn away, and over two hundred soldiers were drowned. The strength of the work was subsequently increased until the breakwater had a base about 300 feet in breadth; and in 1838 it was decided to build a wall of masonry along its crest. Whether this was absolutely necessary as a protection against storms or to sustain the water-batteries that extend its whole length, is not certain on casual observation. The work was finished in 1853, and the total cost of the breakwater proper, excluding the four casemated forts, is reported at nearly $17,000,000. This is one and a half times greater, per linear yard, than the Holyhead breakwater; two and a half times greater than that at Portland; but one-quarter less than that at Alderney. It is only one-sixth less, per linear yard, than the Admiralty pier at Dover. The breadth of the base of the breakwater is about the same as that at Portland and Holyhead, and it probably would have suffered less than it has done from the destructive action of the seas had it been constructed in deeper water; but as the whole idea of Napoleon was solely to protect a naval and not a commercial port, it is more than likely that the position was made subservient to the protection afforded by the adjacent forts on the east and west of the passages and on the surrounding heights. The four forts on the breakwater itself mount 174 guns, and the intermediate water-batteries add 96 more.

Brest; naval and commercial docks.—The naval docks and depots of Brest on each side of the Penfeld have an average width of 110 yards. The rise of the banks is quite sharp and about 100 to 150 feet above the water. Both sides of the stream, which is really a very narrow arm of the sea are occupied on the banks and heights with arsenals, workshops, docks, ship-building slips, depots, hospitals, casernes, &c., of the second naval dock-yard of France.

The high iron bridge—the Pont Impériale—over the Penfeld, is the first special object to attract attention. It is composed of two flying wings, each pivoted upon a tower or pillar of masonry about 80 feet above the water. The distance between supports is about 414 feet, and the approaches to carry the counterbalancing weight each about 100 feet. The breadth is 25 feet. It is a light, graceful structure, easily moved by three men at each wing, and although the vibration of a few persons passing it is felt, the weight is 750 tons, and its strength has been amply tested; nevertheless, in the form of the angle-iron of the lower chord, there appears an erroneous application of material. The iron-work of the bridge cost $282,000, and the masonry, buildings removed, approaches, &c., cost nearly an equal amount. Another object of interest was the economy-crane, for lowering the heaviest machinery and masses directly into the vessel from the workshops on the heights above the right bank. A viaduct has been carried over a single arch of 100 feet span to the pillar containing the machinery for moving the crane. The largest dry-dock is situated one and a half miles inside the entrance to the Penfeld, on the right bank. It is 715 feet in length and 80 feet in width, divided into two parts by a middle gate so as to be used as two docks, if necessary. All the gates are of iron, and are so constructed as to be floated and moved about in a vertical position. The condition of the masonry of the quays along both banks of this naval port indicates that the foundations are not good; and at two of the ship-building slips the foundations had, at one time, actually slipped away in part; but by going to the "bed-rock" for foundation no difficulty is experienced.

But the most instructive work visited was for the improvement of the commercial harbor and docks just eastward of the Penfeld, and founded in 1858. The road of Brest not being capacious, it has been deemed necessary to build a breakwater in front of the new commercial quays and docks. But this protection is crowded so close upon the quays, that at the western head there is a passage-way of only ninety yards between it and one of the quays. The passage at the western head is but a little wider, and the dockage for vessels is very limited in extent.

The bottom of the road or bay under the shore-line is mud of several meters in depth, as marked on the accompanying rough sketch (illustration No. 30, sketch 4 A.) In constructing the front wall of the quay, a considerable depth of this mud was dredged away, but a depth of 10 feet was left above the hard bottom. Upon the inner line of this dredged section a base of riprap was laid, having a breadth of 33 feet and a height of 12 feet. Upon this was then built the masonry wall, as shown in the same sketch, which exhibits a cross-section of the work. Earth was then filled in behind this retaining-wall to the required level. The mud under the earth, yielding to the superincumbent mass, was forced against and under the retaining-wall and carried the wall forward with it,

At one place, part of the wall was 325 feet from its position. The progress of this movement was regularly observed and measurements were taken to exhibit the canting of the wall and its actual change of place.

To remedy this mistake, the mud was dredged to the solid bottom of the bay, and a riprap laid having a breadth of base 131 feet (illustration No. 30, sketch 4 B) and a greater depth than the first one. The retaining-wall was then built upon the outer edge of the upper part as before.

To the end of 1873, the total cost of improvements had been $3,072,000 (16,383,000 francs). According to the plans, the present works exhibit 3,380 yards of dock and quay frontage, and at the foregoing rate of expenditure will certainly reach $1,000 per yard of frontage before the work is closed. It is the most expensive piece of work examined in Europe; but it has already been proposed to enlarge the scheme, and to continue the docks and quays to the eastward, without a prolongation of the breakwater. Along the quays railroad-tracks are to be laid, and turn-tables at every change of direction, and large store-houses are to occupy the quays.

The Admiralty pier, Dover; a breakwater of masonry; how constructed; illustrations; cost.—At Dover, Mr. Druce, the resident engineer of the Admiralty pier, exhibited sections of the pier as modified during the last twenty-five years. The pier, as it now projects from the western part of the old contracted harbor-pier, is but one part of a yet undetermined project to build a great artificial harbor. In ordinary southwesterly winds, small steamers find protection on its northeasterly side; but in heavy northeasters they must seek shelter under the southwesterly side. The main idea in building this breakwater is that it shall be of solid masonry, and present a nearly vertical wall to the action of the waves. It is constructed in the very best manner, and at the close of each season's work the unfinished extremity of the pier is left without special protection until the next spring. The first section of the work has an outer shell (A) of granite (illustration No. 30, Sketch 5), of which shell the blocks below low water were not cemented; next inside this is a line of rubble (B), and within that a hearting of concrete (C), all carried down to the hard chalk. The plastic chalk overlying the hard, although so tough as to make its removal comparatively expensive, was cleared away. The batter of the walls was 1 foot in 4, and has been gradually changed until it is now 1 foot in 12, with more satisfactory results in regard to the action of the water; practically, the walls may be considered vertical. The form of construction of the three parts, A, B, and C, was modified as the pier advanced; and the rubble (B) was replaced by solid masonry, and the inner faces toward the hearting were made vertical. As the work advanced, the hearting was abandoned, and the whole pier is being carried out with solid blocks of sandstone, but faced with granite. The work was advanced during winter below the low waters, so as to be beneath the reach of the heavy wave-action. During summer, the upper part is carried forward; but at present the work is suspended.

Divers in armor are only employed incidentally on account of the turbid waters and the strong current from the northeastward, especially during heavy weather. All the blocks are set, and nearly all the work is done by the aid of the diving-bells, which are of such size as is found by experience to be the most advantageous, and the blocks are of such size that they can be readily managed from the diving-bell. Even in heavy weather the work can be carried on in this way at the greater depths by first rapidly lowering the diving-bell with the men and the blocks through the troubled water, and then lowering more slowly toward the bottom. Instead of large blocks the engineers especially favor smaller and more readily handled blocks below the water-level. They can be better set and cemented. The cement is one part Portland to three of lime, and is very hard. The scaffolding from which the bells and blocks are lowered has been gradually increased as the pier advanced so as to be above the reach of the waves; since the abandonment of the work, the scaffolding has been removed.

The extremity of the pier is now 700 yards out, and just includes the enlargement on the inner face for an iron turret-fort with two heavy guns. It is in 45 feet water at low tide, and there is not a sign to indicate settling or rupture. The top breadth is 45 feet, and the top of the parapet is 40 feet above the level of low water, the tides rising 19 feet. The parapet, which was to be solid masonry, has been modified so as to admit traffic in combination with the two railroad termini upon the pier; it now has the general section indicated in illustration No. 30, sketch 6. The upper footway of stone flooring upon iron plates is supported on one side by the wall,

and on the other by a line of iron pillars; and the space beneath is open for traffic. There is an iron railing on the inner side of the parapet footwalk, and also upon the edge of the pier. This open space was to have been solid, but the engineer thinks the modification quite strong enough. The parapet is finely dressed granite from Cornwall, this extra finish being added by order of the Admiralty. It is estimated that the ordinary smooth work on the inner edge and the top of the blocks adds only 2 per cent. to the cost of ordinary work; but the additional expense upon the parapet must be much greater. The roadway is in Belgian blocks of about 3 inches by 12 on the surface; they are well laid, and the interstices small. The béton works are at the inner edge of the pier.

Cost.—The work is unquestionably good, but the cost is very great. Exclusive of $120,736 paid for work on the fort, the 700 yards already completed to 45 feet at low water has cost $3,361,423, or $4,802 per linear yard.*

According to a scheme presented to Parliament, in the session of 1874, for the completion of the whole Dover harbor-works, piers of a total length of 2,317 yards additional are required. Should they cost at the same rate as that already built, the whole work would demand an expenditure of $14,500,000.

Although the waves and heavy driving spray frequently cover the parapet in southwesterly winds, it is never exposed to such seas as are experienced on the Northern Pacific coast in winter, or even to the heavy groundswell of northwesters.

Portland breakwater; riprap; description; illustrations of cross-section; cost.—This work differs totally in character from that at Dover. This is a great dike of *pierre perdue* (riprap) dumped upon a given line until raised above the level of the sea, and having its cross-section shaped by the action of the waves. The first impression received is that the seas which fall upon this breakwater are not such as fall on the Northern Pacific coast in winter, or even like seas raised by our strong northwest winds; because the comparatively small blocks would be torn away and driven or rolled over into the harbor, and the very pillar-scaffolding, which remains just above the stones along the water-edge, would be broken off, notwithstanding their shortness; and yet it is said at Portland that a very heavy swell does break upon and over, and at times lifts the blocks. On the seaward face, exposed to the southeast or line of greatest exposure, the finer material of the breakwater is driven out; but on the inner slope this is packed in with the larger. The irregular masses of rock appear to average barely 1½ cubic yards. As taken from the quarry, they range in weight from one ton to five tons.

The breakwater stretches from the northeast part of the Great Head of Portland toward the east-northeast into 10 fathoms of water, and then stretches to the north in about the same depth. The total length of the outer breakwater is 6,500 feet, and of the inner 1,900 feet, with a 9½-fathom passage 400 feet in width between them and just inside of the curve. It is a successful work. The original project contemplated the building of a line of masonry and parapet on the inner edge of the breakwater, from low water to nearly 30 feet above high water. But there is only a line of this parapet-wall on the inner breakwater, and it is not intended to add anything to the outer length. Upon the inner side of the wall of the inner breakwater there is a coaling-station for men-of-war, but it is not now used. So far as the lines of scaffolding remain in the line of the breakwater, and as the cross-sections show, there has been very little change in the pier; but additions were made to the sea-face as the whole cross-section fell into shape. A good proof of stability is seen in the small amount of yearly expenses, the pay of men, repairs, and maintenance being only $2,425. The annual appropriation for "storm-repairs" is only $970. At Plymouth breakwater the annual repairs cost from $25,000 to $30,000; and they are much more at Alderney.

Along the inner side of the breakwater a tram-way is to be laid above high water to permit a movable crane to readily traverse its length and replace blocks that may be driven inward by the storms. The heaviest effects of the gales are upon the bend of the outer length of the breakwater, but no special widening has been found necessary. The walls and the masonry foundation of the fort have been badly cracked, but the plans show that this heavy mass of masonry, 100 feet in diameter, was built upon the riprap deposits made between April, 1862, and June, 1863. The riprap is 20 feet thick under the masonry at low water.

Cost of breakwater.—The breakwater was virtually completed about 1865, and up to 1869 its

* *Dover pier.*—Return to an order of the House of Commons dated 22d April, 1875, for copy of quarterly report, &c.

cost had been $4,478,000, or $1,742 per linear yard. This is a little more than one-third that of Dover pier and two-thirds that of the Holyhead breakwater. But it should be borne in mind that the stone was quarried in the hill directly over the works; that the loaded dump-cars were carried down by gravity, and the empty ones drawn up by those descending, and that a large amount of convict-labor was utilized, as it is there to-day. Two cross-sections are here given of the breakwater (illustration No. 30, sketches 7 & 8), exhibiting the satisfactory manner in which it has maintained its form. That numbered one hundred is taken near the bend where the heaviest seas break upon and over it; that numbered two hundred and sixty is very near the fort. At both points, the depth of water outside the breakwater is 10 fathoms at low tide. These may be advantageously compared with the cross-section of the Holyhead breakwater. The noteworthy, almost identical, form indicates that the same general laws have been at work shaping the masses, notwithstanding the latter has slightly the larger cross section and the wall of masonry. From these and other examples it may be possible to deduce the law of cross-section for riprap breakwaters, and the most favorable depth of water for building, under varying conditions.

Refuge.—While examining this structure, a count showed thirty-three large vessels at anchor from the bad weather outside; on the day before, there had been about one hundred and fifty craft of all sizes.

Holyhead breakwater; riprap and wall of masonry; description; cost; illustration.—This great breakwater is similar to that at Portland, except that it carries a wall and parapet of masonry its entire length upon the harbor side. From a full description of the work by Mr. Harrison Hayter, for the institution of civil engineers of London, only the main features of the work and a tracing of the cross-section will here be given, as kindly furnished by that gentleman (see illustration No. 30, sketch 9). The breakwater has a total length of 7,860 feet, and embraces a sheltered roadstead of 400 acres, besides the inner or "New Harbor" of 267 acres. The original conception of the work was due to Rendel, and although embracing only the 267 acres just mentioned, was considered a very bold and even wild undertaking. Yet this was found inadequate for the necessities as a harbor of refuge for which it soon became invaluable. The original breakwater stretched 5,360 feet into 8 fathoms of water; the recently finished prolongation of 2,500 feet runs into 9 fathoms of water. Very fortunately for such a great undertaking the stone used in the construction of the work was obtained as at Portland, from an adjoining hill, and was readily conveyed to the line of the work. The material is a quartz-rock. The operations in quarrying, among the largest and most interesting that had been undertaken, need not be detailed here. The stone was dumped into the sea from 250 iron tipping-cars, running over a temporary wooden scaffolding. The inclination given to the foreshore was 1 in 7, and this was supposed to continue 10 feet below the low-water level, after which the material would assume a slope of 1 in 2 for the next 15 feet of depth; and then 1 in $1\frac{1}{2}$ to the bottom. On the harbor side, the slope was 1 to 1. At the lower-water line the breakwater was to have a breadth of no less than 250 feet; and in 50 feet of water the breadth of the base was 400 feet, or 80 feet more than that of Portland in 60 feet of water. These conditions have become somewhat modified, and the existing foreshore slope between high and low water is 1 in 12. The breakwater contains 7,000,000 tons of rubble-stone, and after it had become consolidated the superstructure was erected. The main object of this wall is to shelter the inner harbor more effectually, and to prevent the loose rocks from washing into the harbor. Of course, the seas cannot be so great here as at Alderney, where rocks of 10 tons are lifted over the 40 feet wall and deposited inside. The wall has been designed so that jetties may be thrown out therefrom in order to afford convenient wharfage space if this is ever needed. It is a solid central wall of masonry built of quartz-stones, many of them of very large size, some weighing upward of 15 tons, and the work is set in lias lime mortar. The foundations are laid at the level of low water, for which purpose the rubble had to be excavated; and it was built as near the inner edge of the breakwater as practicable in order to allow as long a foreshore as possible. This solid barrier is carried to a height of 39 feet above low water; upon this is a handsome promenade, protected on the seaward side by a massive parapet. At a lower level, 27 feet above low water, there is on the harbor side of the main wall a terrace or quay 40 feet broad, formed by an inner wall built at a distance from the main wall, and the interspace is filled with suitable material.

The head of the breakwater is a massive structure 150 feet long and 50 feet broad. It is

founded upon the rubble at a level varying from 20 feet to 28 feet below water, and is built of ashlar masonry. The blocks composing it are of limestone, and were laid by divers with helmets. Upon this head is placed a red revolving dioptric light of the third order. An average of 3,500 vessels yearly seek this harbor for refuge against storms. Few harbors possess greater facilities for entering and leaving; and the holding-ground is good.

The cost of this north breakwater and the works connected therewith, including land, has been $6,232,250, or $2,608 per linear yard, being nearly $1 per ton of rock in the riprap. There are no extensive repairs required, and there has been very slight wear up to date. There is a slight littoral movement to the northeastward along the line of the extension.

The present Holyhead and Dublin packet-service leaves the pier at the old harbor, where there is only 14 feet of water, but the western part of the inner or "new harbor" has 30 feet at low tide.

The general cross-section of the breakwater is very nearly identical with that of Portland; but there are certainly heavier and more violent seas at Holyhead, as indicated by the necessity for the masonry wall and by the flattening of the foreshore, from which part of the material has been driven to the wall, and part washed down into deeper water.

Alderney breakwater.—In regard to this breakwater the general opinion of engineers is that the whole riprap has settled or sunk irregularly, so that the superstructure which was built upon it has been broken. This result has been partly aided or hastened by the peculiar shape of the cross-section, but the lower courses of masonry in the wall were laid without cement. Drawings of the cross and longitudinal sections (illustration No. 30, sketches 10 and 11) exhibit the peculiar form of the bottom upon which it was laid, and the exceptional form and relative smallness of the cross-section.

Even when the wall was under construction, "subsidence was the inevitable result of setting even a single course on the top of this great embankment. The walls by their weight compressed like a sponge the mass of loose stones below them."* But the form of this wall is singularly defective; "the part of the superstructure above low water is solid; the part below low water consists only of two side-walls, the sea-face of which batters at a very considerable angle." "Between these walls is loose rubble not consolidated even by the action of the waves." "There is, therefore, a solid wall standing upon two props, as it were; and these props rest on a spongy mass."* Not only did the settlement of the riprap tend to split this wall vertically in its length as well as crossways, but, as if to accelerate the destruction, it appears that the large stones intended to form a covering to the dike of stone upon which the wall is laid, as well as to other additions to the dike, were thrown from the top of the wall into the sea, and in falling struck the projecting courses of the wall, cemented and uncemented, and loosened them. It only required the destructive action of the sea to hasten the dislocation of the whole wall.

The manner in which the great dike of rubble-stone was laid was wholly different from that at Portland and Holyhead. Here the stone was of all sizes, from four tons to less than an ounce; brought in "hopper barges" from the quarries on the island, and dropped on the line of the breakwater. From reliable data, the resident engineer calculates that the interstices in the great mass are equal to one-third of the whole volume. From the manner in which it was dropped, this material took the natural slope from a surface breadth of 156 feet, at a depth of 12 feet below the low tides. At this height it remained until it was supposed to be consolidated by the sea. This height for the rubble embankment was decided upon from observing that the heaviest seas rarely disturbed the surface of the rubble. Upon this surface the masonry was laid and built as described, and the effect of the superstructure has been to sink an average of 4 feet into the loose mass beneath it; and the irregular subsidence has broken the wall in every direction.

At the same time it must not be overlooked that the position and locality of the breakwater are particularly and peculiarly exposed. The whole ground-swell of the Atlantic breaks fairly and squarely upon it with great fury, and for months at a time it has been impossible to carry on any work. For four hours near high tide the greatest weight of the green seas comes over it, but the damage to the wall does not then take place, as they pass clean into the harbor with a

* Report from the select committee of the House of Lords on the harbor and defenses of Alderney, &c.; session 1872; Blue-book, 56.

leap. For four hours toward the last of the low tide the heaviest blows are given to the wall; the waves throw sheets of water a mile in length and 300 feet high as they strike the wall. And such is the power of the down-falling mass of water that the rails laid upon the wall, with only one inch exposed, are torn away. Large blocks are "drawn out" of the seaward face of the wall, and the heaviest stones are swept bodily over the parapet into the harbor.

The action of the sea upon the rubble embankment, when it was carried 600 yards in advance of the wall, was wholly different. When the ground-swell (even without wind) was heavy, the rollers began to comb in 50 feet of water on the west slope of the breakwater, and they broke in 30 feet from end to end. But the breakers on top of the embankment, when its level was 12 feet below the surface, were overhanging walls of green water from 12 to 15 feet in height, and they died out gradually from 100 to 150 yards to the eastward of the termination of the wall.

Various projects have been proposed to remedy the inherent defects of construction, but none has been decided upon. The principal remedy is doubtless more material to the foreshore, up to the height of the top of the wall, until it acquires the natural slope under such circumstances: the removal of the parapet and additional material to the inside. The principal stress for this failure has been laid upon the settling of the rubble embankment and the weak section and construction of the wall and parapet; yet the longitudinal section must not be overlooked, showing the irregular slope of the bottom, and the extraordinary depth of 132 feet at low water (and 150 feet at high water), to which it has been carried with such a minimum of poor material. In the Holyhead and Portland breakwaters, the depth may be said to be nearly uniform; here the grade is larger, and there are irregularities of bottom. In the latter cases, the wave-action must be more uniform in character; in the former, the reverse will be the case. The present breakwater appears to be one of six schemes proposed, the fifth and sixth carrying the work to great depths; but progress was arrested, and only such additional work done as to preserve what had been built. In order to provide greater strength at the extremity of the pier, the masonry for 60 feet in length has been founded 30 feet below the low-water line. It is faced under water with granite headers round the extremity and on the harbor side, with backers of Portland cement blocks, built solid across, between the sea and the harbor walls. The total length of the breakwater is 4,827 feet, and, so far as could be learned, it had cost not less than $8,500,000, or $5,480 per linear yard.

CONCLUSIONS.

The practical question that naturally suggests itself after an examination of the foregoing harbor works, and looking at them with special reference to the construction of harbors on the Pacific Coast, is: What is the best and most readily-applied form of breakwater for the smallest amount of money? Those who know the Pacific coast can readily understand that a perfectly safe breakwater of any form that would satisfy the conditions required for a breakwater in the Bay of San Pedro would not fulfill the conditions demanded at Crescent City or Port Orford.

At the first-mentioned roadstead, the only disturbing gales are from the southeast during the rainy season; and very moderately-sized vessels with good ground-tackle can ride them out with safety. In that latitude the gales are not severe, nor are they of very long duration.

At San Pedro, or at almost any point south of San Francisco, the form of breakwater at Portland would suffice, and it could be readily constructed. But at Port Orford, where very heavy December storms prevail from the southeast of one and two weeks' duration, the proper form would be that of the Portland breakwater, developed to a much greater section and of larger materials; or that of Holyhead, also of larger section and with its expensive superstructure of masonry. And in case a wall were necessary, no vertical face whatever should be exposed to the sea-front if the wall is liable to rupture.

Without considering the matter of cost, if the foundations were perfectly reliable, in almost every case the nearly vertical solid masonry wall, as at Dover, would give the greatest degree of safety for the least amount of material. But when questions of expense and of facility and rapidity of execution are involved, the riprap forms have great claims to be considered. For instance, there is hardly a southerly-exposed anchorage on the Pacific coast of the United States that is not commanded by high, rocky heads, from which material can be readily and cheaply obtained, and transported by gravity to the works. There is a comparative scarcity of granite and lime-

stone at these same localities for building walls, if these are necessary, yet other hard stones are in abundance for the main bulk of the embankment. And it should not be overlooked that the peculiar qualities of the rock, including the forms it takes in quarrying, have an important bearing upon the wear and tear of the foreshore, and especially the liability of the blocks to be readily torn away.

The foundation for solid walls must be perfect, otherwise they should never be used in great works. The piers of the North Sea harbor of Amsterdam demonstrate the weakness of the solid vertical pier when the foundation is unreliable; the pier at Dover shows its full advantages when over a satisfactory bottom.

The North Sea harbor piers have become merely a retaining-wall for the riprap of concrete blocks upon the seaward face; and should their integrity be further injured, they will become, in time, part and parcel of the rubble-work itself. If the predictions of competent engineers be weighed, the wall upon the Alderney breakwater, unless protected and constantly repaired, will, in time, also be so broken and dislocated as to become part of the *pierre perdue* formation.

The item of expense is vital upon such an extensive seaboard as that of the United States, and especially upon the exposed coast of the Pacific; so that although theoretical demonstrations might point to the nearly vertical solid pier as the best, yet if two safe breakwaters of riprap, or riprap properly coped, can be built for the cost of only one like the Dover pier, there can be no hesitation which form to adopt.

It should not be forgotten that the piers mentioned and partially described, have, in every case but that of Cherbourg, one end anchored to the shore. This does not include Brest, because it partakes more of the character of an inside-harbor work. Although that is a great advantage in the execution of the work, it cannot always be adopted along the Pacific coast, because the littoral drift carries its load of sand invariably to the northward, as has been pointed out in a discussion of the law governing the formation of the bars and channels of the harbors and rivers on the Pacific, from latitude 24 to latitude 49.

The depth of water in which breakwaters should be built is a very important question in regard to their stability, and in the wear and tear. For instance, a breakwater in 5½ fathoms, on the bar of San Francisco, or on that of the Columbia River, would be almost impracticable. It could hardly be made of sufficient strength. In 7 fathoms of water it would be on the line of the heaviest breakers on the coast, although very heavy northwesterly and southwesterly ground-swells have been known to break in 9 fathoms. Looking also to the future, when our commerce will have largely developed, the safest and most advantageous depth in which to found a breakwater of the first class, is probably not less than 10 fathoms at low tide.

Fascinage for breakwater foundations.—The fascinage-work of the Dutch engineers has necessarily played an important part in all their works of reclamation, and has been introduced in the foundations for moles, &c.; but it must be recollected that it has not been adopted from choice, but from necessity. The Netherlands is a vast alluvial deposit, in many places below the level of the sea. Stone for works of construction cannot be had except at immense expense and time; and timber is not found in sufficient quantity or size to be employed so lavishly as in the United States. Basalt is brought from the Rhine, granite from Norway, limestone from Belgium, and timber from the shores of the Baltic. Thus the engineers have been compelled to use fascinage, and with great success, too, in many of their undertakings; but it is yet an open question how it will last in extensive works of engineering, such as that carried on at the mouth of the Scheur to connect Rotterdam with the sea by a channel capable of admitting the largest ocean-vessels. Where they become thoroughly silted up with sand they may not be liable to destruction by animal life, but they are liable to decay. And we have yet to learn the effects that may be wrought on them by great storms with heavy ground-swell, and by strong currents.

As foundations of great works projected into the sea upon the Pacific coast, little or no faith would be accorded to fascinage, except as partially preventing scouring during the laying of foundations under peculiar circumstances. No wall could be built upon it without certainty of fracture. For river corrections of all classes, and for reclamation in quiet waters, it would be, no doubt, very efficient, if not subject to decay.

The docks of the maritime cities of Europe are a feature of which we have no example in the

United States; but they are there necessitated by the limited harbor area and by the excessive rise and fall of the tides. The structures seem built for a thousand years, and the cost of their repairs is surprisingly low. In 1865 it was stated by the chief engineer of the Liverpool docks, that with a yearly expenditure of $3,600,000 for new works, the annual outlay for repairs upon all the existing docks was less than $5,000.

Each and every proposed change or addition to a harbor or water-course undergoes the severest scrutiny of a government commission before it is sanctioned by Parliament; and whatever is in the least detrimental to the integrity of the harbor or stream is rejected.

River improvements.—Opportunity did not offer for examining the great improvements at the mouth of the Danube or of the Rhone. In the former, the system of prolonging the natural banks by artificial means is reported successful; at the Rhone, similar means were unsuccessful, and the system of side canals has been substituted.

The two rivers are essentially different in their constitution. The Danube is not a river that forms deltas rapidly; with its course of 1,700 miles, and a drainage area of 300,000 square miles, it has formed a delta of only 1,000 square miles, and it discharges into a tideless sea. Moreover, the works of the Sulina are chosen upon that ramification where there is but one mouth, through which only one-fourteenth of the Danube waters pass; so that even if the materials in suspension were brought down this branch, very little would be deposited in the mouth Compared with large delta-forming rivers, the material in suspension is very limited in quantity, and the bars appear to be the combined effects of the littoral drift and the river detritus, as in most of the harbors of California. Part of this bar material is brought from the Georges branch across the Sulina mouth by the drift from the southward.

On the contrary, the Rhone is emphatically a delta-forming river like the Nile, the Ganges, &c., as demonstrated by the rapid progress which the bar made seaward when the moles were projected beyond its mouth. On this account, the prolongation of the natural banks by artificial means was abandoned, and the side canals adopted with success.

Throughout the countries visited, evidence was everywhere present of the systematic endeavor to preserve the river-courses within their legitimate bounds. On the Po, on the Ticino, Sesia, and other torrential streams of Italy, and even among the mountain-streams, provision has been made to prevent the wearing away of alluvial banks, and as far as practicable the overflowing of arable lands. So through Austria and the German Empire. Even where the Danube is little more than a creek, its banks are in many places revetted with stone; and in some cases the bottom is paved roughly with stone to prevent erosion where the fall is considerable. From Linz to Vienna the banks are well protected wherever there is danger of abrasion. At Vienna, a few months after the official opening of the improved channel, the engineer-in-chief was preparing a full set of plans and models to illustrate the improvements and works, for the Austrian section of the Centennial Exhibition at Philadelphia.

On the Elbe, the Moldau, and the Rhine, on the Oder and the Weser, the integrity of the banks and the preservation of the channels are paramount objects of solicitude to the government and to the people. The improvements (corrections) have evidently been made at comparatively small expense, and yet with such good judgment and foresight as to lead to the happiest results.

The improvements of the Seine at Paris and of the Thames at London, more
embankment upon the latter, are not only works of utility but
out all no timber is used where perm

APPENDIX No. 19.

FORMULÆ AND FACTORS FOR THE COMPUTATION OF GEODETIC LATITUDES, LONGITUDES, AND AZIMUTHS.

When we know the geographical co-ordinates of latitude and longitude of a point on the earth's surface, and the distance and azimuth to another point, we may treat the problem of computing the latitude and longitude of the second point and the reverse azimuth in two different ways.

We may either solve the spheroidal triangle formed by the two points and the pole as a whole, arriving at trigonometrical functions of the sought co-latitude, azimuth, and difference of longitude; or we may seek expressions for the differences of the sought from the given data.

The former or direct method has the inconvenience of requiring the use of ten places of decimals in the computation, in order to give the positions with a degree of exactness corresponding to that of the known distance between the two points, while the second leads to very convenient expressions, on account of the smallness of the differential arcs in most cases of triangulation.

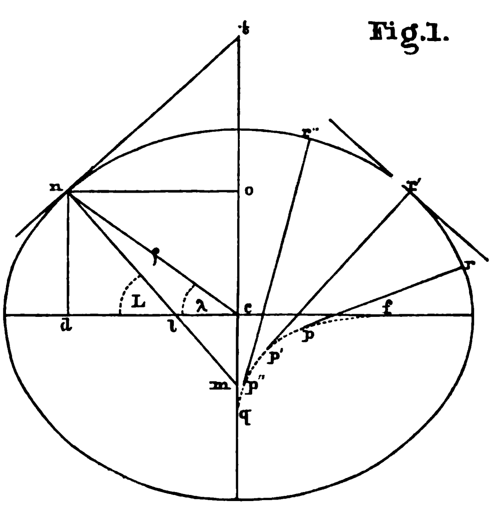
When, however, the arc between the two points reaches several degrees in length, the direct method must be resorted to. This solution has been very completely and elegantly performed by BESSEL, and is given in *Astronom. Nachrichten*, No. 86, 1826.

Adopting the second method, we follow in the main PUISSANT (*Traité de Géodésie*),* in the development of the difference of latitude of two points on the spheroid in terms of the distance, azimuth, and latitude of the given point. It will be convenient first to recall the expressions of several lines of an ellipse in terms involving the latitude, L, which is the angle that the normal to any point on the ellipse makes with the major axis.

Designating the major or equatorial semi-axis by a, the minor or polar semi-axis by b, then the *ellipticity* or ratio of their difference to the former is—

$$\varepsilon = \frac{a-b}{a}$$

Fig. 1.



The eccentricity e is expressed by—

$$e^2 = \frac{a^2 - b^2}{a^2}$$

being shown in the figure by cf, the distance from the centre to the focus;

The normal—

$$n\,l = \frac{a\,(1-e^2)}{(1-e^2 \sin^2 \mathrm{L})^{\frac{3}{2}}}$$

The normal $n\,m$ produced to the minor axis—

$$\mathrm{N} = \frac{a}{(1-e^2 \sin^2 \mathrm{L})^{\frac{1}{2}}}$$

The abscissa—

$$c\,d = n\,o = \mathrm{N} \cos \mathrm{L}$$

this is the radius of a parallel on the spheroid;

The tangent $n\,t$ ending at the minor axis $=$ N cot L

The ordinate—

$$n\,d = \frac{a\,(1-e^2) \sin \mathrm{L}}{(1-e^2 \sin^2 \mathrm{L})^{\frac{1}{2}}}$$

* Traité de Géodésie. Par L. Puissant. Third edition. Tom. I, Chp. XV. Paris, 1842.

The reduced or geocentric latitude being λ, we have—

$$\tan \lambda = \frac{b}{a} \tan \mathrm{L}$$

The radius vector—

$$\rho = a\,(1 - e^2 \sin^2 \lambda)^{\frac{1}{2}}$$

The radius of curvature, $r\,p$, $r'\,p'$, $r''\,p''$, at any point on the ellipse, is—

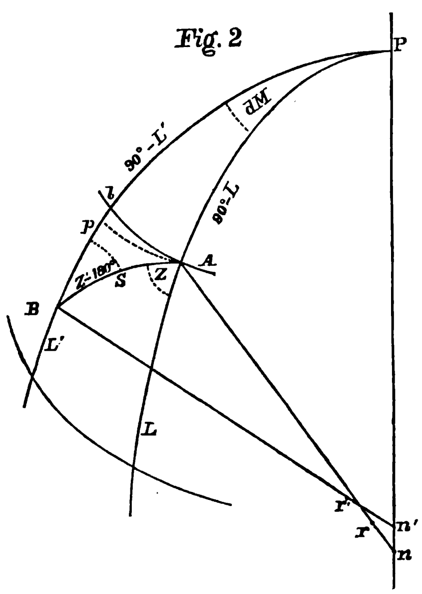
$$\mathrm{R} = \frac{a\,(1 - e^2)}{(1 - e^2 \sin^2 \mathrm{L})^{\frac{3}{2}}}$$

The terminal points, f, p', p', p'', q, form an evolute; at the equator, where $\sin \mathrm{L} = 0$ $\mathrm{R} = \frac{b^2}{a}$ and the centre of curvature is in the focus; at the pole, where $\sin \mathrm{L} = 1$, $\mathrm{R} = \frac{a^2}{b}$

The radius of curvature, R, and the normal, N, are the principal functions used in geodesy. It will be observed that radii of curvature for different latitudes do not intersect unless produced, and that when they lie in different meridian planes on the spheroid they will not intersect at all.

A, B, in Fig. 2, are two points on a spheroid of revolution, having the latitudes L, L′, and joined by the geodetic line $A\,B = s$, making the angles with the meridian, $P\,A\,B = 180° - Z$, $P\,B\,A = Z' - 180°$. The azimuths, Z, are reckoned from south around by west in consequence of the latitudes being reckoned from the equator toward the poles, by settled custom, without which the meridional co-ordinate of a point would be more properly measured from the pole, and the azimuth of a line reckoned from the north. The angle $A\,P\,B$, between the two meridional planes passing through A and B, is the difference of their longitudes, M, M′, which being reckoned positive to the westward, we have $\mathrm{M}' - \mathrm{M} = d\,\mathrm{M}$. Furthermore, $A\,n$, $B\,n'$, $A\,r$, $B\,r'$, indicate the normals N, N′, and the radii of curvature in the meridian, R, R′, at the points A and B.

Fig. 2



This being premised, and the latitude L of the point A being given, as well as the length K of the geodesic line $A\,B$, and its azimuth Z, we propose to find the latitude L′ of the point B, the angle $d\,\mathrm{M}$, and the reverse azimuth Z′, by solving the geodetic triangle $A\,B\,P$. Writing λ, λ', for the co-latitudes, ξ for $180° - \mathrm{Z}$, and s for the arc $A\,B$, referred to radius $= 1$, we have, in a spherical triangle, for λ' the following equation:

$$\cos \lambda' = \cos \lambda \cos s + \sin \lambda \sin s \cos \xi$$

Observing now that s is always a small arc, rarely exceeding 1°, and generally less than 30′, we can develop the increment of λ with reference to that of s in a rapidly converging series, and will have, by Taylor's theorem—

$$\lambda' = \lambda + \frac{d\,\lambda}{d\,s}\,s + \frac{1}{2}\,\frac{d^2\,\lambda}{d\,s^2}\,s^2 + \frac{1}{6}\frac{d^3\,\lambda}{d\,s^3}\,s^3 + \ldots \qquad (a)$$

In order to determine the differential coefficients, we consider a differential spherical triangle having the sides λ, $d\,s$, and $\lambda + d\,\lambda$, in which—

$$\cos(\lambda + d\,\lambda) = \cos \lambda \cos d\,s + \sin \lambda \sin d\,s \cos \xi$$

and, by the known processes of the differential calculus, we find—

$$\frac{d\,\lambda}{d\,s} = \cos \xi \qquad \frac{d^2\,\lambda}{d\,s^2} = -\sin^2 \xi \cot \lambda \qquad \frac{d^3\,\lambda}{d\,s^3} = -\sin^2 \xi \cos \xi\,(1 + 3 \cot^2 \lambda)$$

Introducing these values in (*a*), we obtain—

$$\lambda' - \lambda = s \cos \xi + \frac{1}{2} s^2 \sin^2 \xi \cot \lambda - \frac{1}{6} s^3 \sin^2 \xi \cos \xi (1 + 3 \cot^2 \lambda) + \ldots$$

and substituting L, L′, and Z into this expression, we have, for the difference of latitude—

$$\mathrm{L} - \mathrm{L}' = s \cos \mathrm{Z} + \frac{1}{2} s^2 \sin^2 \mathrm{Z} \tan \mathrm{L} - \frac{1}{6} s^3 \sin^2 \mathrm{Z} \cos \mathrm{Z} (1 + 3 \tan^2 \mathrm{L}) + \ldots \qquad (b)$$

It will be readily seen that the first term expresses the distance on the meridian *P B* from *B* to *p*, the foot of the perpendicular from *A*; the second term, the distance very nearly from *p* to the parallel passing through *A*; while the third term is a further approximation, and so on.

Referring now our case to an imaginary sphere, having the radius equal N, or its centre at the point where the normal *A n* intersects the polar diameter of the spheroid, we have—

$$s = \frac{\mathrm{K}}{\mathrm{N}}$$

substituting which we have—

$$\mathrm{L} - \mathrm{L}' = \frac{\mathrm{K} \cos \mathrm{Z}}{\mathrm{N}} + \frac{1}{2} \frac{\mathrm{K}^2 \sin^2 \mathrm{Z} \tan \mathrm{L}}{\mathrm{N}^2} - \frac{1}{6} \frac{\mathrm{K}^3 \sin^2 \mathrm{Z} \cos \mathrm{Z}}{\mathrm{N}^3} (1 + 3 \tan^2 \mathrm{L}) + \ldots \qquad (c)$$

This difference of latitude is, however, referred to a sphere whose radius is N, and requires still to be transformed by referring it to one whose radius is the radius of curvature in the meridian for the middle latitude, R_m. Since we do not at first know the middle latitude, it is more convenient to refer to the radius of curvature R of the starting-point, the latitude of which is known, and then seek the small correction due to the ratio of R to R_m

Multiplying, then, equation (*c*) by $\frac{\mathrm{N}}{\mathrm{R}}$, and dividing, moreover, by arc 1″, in order to express $d\,\mathrm{L}$ in seconds of arc, we get—

$$-d\,\mathrm{L} = \frac{\mathrm{K}}{\mathrm{R} \text{ arc } 1''} \cos \mathrm{Z} + \frac{1}{2} \frac{\mathrm{K}^2}{\mathrm{R\,N} \text{ arc } 1''} \sin^2 \mathrm{Z} \tan \mathrm{L} - \frac{1}{6} \frac{\mathrm{K}^3}{\mathrm{R\,N}^2 \text{ arc } 1''} \sin^2 \mathrm{Z} \cos \mathrm{Z} (1 + 3 \tan^2 \mathrm{L}) + \ldots \qquad (d)$$

The computation of this series is facilitated by tables giving the logarithms of the following factors to the argument of L, viz:

$$\mathrm{B} = \frac{1}{\mathrm{R} \text{ arc } 1''} \qquad \mathrm{C} = \frac{\tan \mathrm{L}}{2\,\mathrm{N\,R} \text{ arc } 1''}$$

moreover, substituting in the third term the value of the first term, designated by *h*, we can write it—

$$\frac{1}{6} h \frac{\mathrm{K}^2 \sin^2 \mathrm{Z}}{\mathrm{N}^2} (1 + 3 \tan^2 \mathrm{L})$$

and tabulate another factor—

$$\mathrm{E} = \frac{1 + 3 \tan^2 \mathrm{L}}{6\,\mathrm{N}^2}$$

when our formula for computation becomes—

$$-\delta\,\mathrm{L} = \mathrm{K} \cos \mathrm{Z} . \mathrm{B} + \mathrm{K}^2 \sin^2 \mathrm{Z} . \mathrm{C} - h\,\mathrm{K}^2 \sin^2 \mathrm{Z} . \mathrm{E} + \ldots\ldots \qquad (e)$$

In order, finally, to obtain the true $d\,\mathrm{L}$ referred to $\mathrm{R_m}$, we must increase $\delta\,\mathrm{L}$ by $\frac{\mathrm{R}-\mathrm{R_m}}{\mathrm{R_m}}\,\delta\,\mathrm{L}$ Now—

$$\mathrm{R}-\mathrm{R_m}=a\,(1-e^2)\left(\frac{1}{(1-e^2\sin^2\mathrm{L})^{\frac{3}{2}}}-\frac{1}{(1-e^2\sin^2\mathrm{L_m})^{\frac{3}{2}}}\right)$$

$$=a\,(1-e^2)\frac{\frac{3}{2}\,e^2\,(\sin^2\mathrm{L}-\sin^2\mathrm{L_m})}{(1-e^2\sin^2\mathrm{L})^{\frac{3}{2}}\,(1-e^2\sin^2\mathrm{L_m})^{\frac{3}{2}}}$$

by developing and neglecting terms involving higher powers of e^2; but—

$$\sin^2\mathrm{L}-\sin^2\mathrm{L_m}=\sin(\mathrm{L}-\mathrm{L_m})\sin(\mathrm{L}+\mathrm{L_m})=\delta\,\mathrm{L}\sin\mathrm{L}\cos\mathrm{L}\text{ very nearly,}$$

because—

$$\tfrac{1}{2}\sin 2\,\mathrm{L}=\sin\mathrm{L}\cos\mathrm{L}$$

hence we write—

$$\frac{\mathrm{R}-\mathrm{R_m}}{\mathrm{R_m}}=\frac{a\,(1-e^2)\,\frac{3}{2}\,e^2\,\delta\,\mathrm{L}\sin\mathrm{L}\cos\mathrm{L}}{(1-e^2\sin^2\mathrm{L})^{\frac{3}{2}}\,(1-e^2\sin^2\mathrm{L_m})^{\frac{3}{2}}}\times\frac{(1-e^2\sin^2\mathrm{L_m})^{\frac{3}{2}}}{a\,(1-e^2)}=\frac{\frac{3}{2}\,e^2\,\delta\,\mathrm{L}\sin\mathrm{L}\cos\mathrm{L}}{(1-e^2\sin^2\mathrm{L})^{\frac{3}{2}}}$$

making—

$$\mathrm{D}=\frac{\frac{3}{2}\,e^2\sin\mathrm{L}\cos\mathrm{L}}{(1-e^2\sin^2\mathrm{L})^{\frac{3}{2}}}$$

we get, for the desired corrective term,—

$$\frac{\mathrm{R}-\mathrm{R_m}}{\mathrm{R_m}}\,\delta\,\mathrm{L}=(\delta\,\mathrm{L})^2\,\mathrm{D}$$

and we finally have, for the true difference of latitude

$$-\,d\,\mathrm{L}=\mathrm{K}\cos\mathrm{Z}\,.\,\mathrm{B}+\mathrm{K}^2\sin^2\mathrm{Z}\,.\,\mathrm{C}+\delta\,\mathrm{L}^2\,\mathrm{D}-h\,\mathrm{K}^2\sin^2\mathrm{Z}\,.\,\mathrm{E}\qquad(1)$$

which formula, although of a somewhat complicated derivation, is very simple and convenient in practical computation, with the aid of the tabulated factors, B, C, D, E. [1] The term $(\delta\,\mathrm{L})^2\,\mathrm{D}$ is here interposed between the second and third terms of the series proper, because the latter is frequently not required, being insensible when the distance K is less than about 10 miles, or log K in metres less than 4.23 The term $(\delta\,\mathrm{L})^2\,\mathrm{D}$ should be used whenever log h exceeds 2.31, and h^2 may be used for $(\delta\,\mathrm{L})^2$ in all cases where log K does not exceed 4.93

The term depending on the fourth differential co-efficient, neglected in equation (a), never exceeds $0''.001$ for $s=1^\circ$, or $\mathrm{K}=100{,}000$ metres, and may therefore be safely neglected in practice.

For secondary triangulation, and when the sides do not exceed about 12 miles, or 20,000 metres, the formula (1) may be advantageously reduced to the following:

$$-\,d\,\mathrm{L}=\mathrm{K}\cos\mathrm{Z}\,.\,\mathrm{B}+\mathrm{K}^2\sin^2\mathrm{Z}\,.\,\mathrm{C}+h^2\,\mathrm{D}\qquad(2)$$

In order next to deduce the angle APB between the meridional planes passing through A and B and intersecting in the polar axis, or the difference $d\,\mathrm{M}$ of the longitudes M and M′ of the points A and B, counted from east to west, we avail ourselves of the latitude L′ of B, which has become known by the previous calculation, and have simply, using the same notation as before—

$$\sin\lambda:\sin\xi=\sin s:\sin d\,\mathrm{M}$$

Referring s to a sphere the radius of which is the normal $\mathrm{B}\,n'=\mathrm{N}'$, we have $s=\frac{\mathrm{K}}{\mathrm{N}'}$ and assuming for the present the small arcs s and $d\,\mathrm{M}$ proportional to their sines, we obtain—

$$d\,\mathrm{M}=\frac{\mathrm{K}\sin\mathrm{Z}}{\mathrm{N}'\cos\mathrm{L}'\,\mathrm{arc}\,1''}\qquad(3)$$

(1) This term was devised by the writer of this article in 1846, while arranging the formulæ for use in the Coast Survey, and putting them into the form above given, in which they have been employed ever since.—J. E. H.

dividing by arc 1″ in order to obtain $d\,M$, expressed in seconds of arc. The table gives the logarithm of the factor $A = \frac{1}{N \text{ arc } 1''}$, which must be taken out for L′.

In order to correct for the assumption that the small arcs s and $d\,M$ are proportional to their sines, we use a table giving the differences of the logarithms of the arcs and sines. This table is given on page 365; in using it, take out the differences for the arguments log K and log $d\,M$, the first with a negative, the second with a positive sign, and add their algebraic sum to log $d\,M$.

We obtain, finally, the reverse azimuth Z′ by considering that in the spherical triangle $A\,P\,B$ (fig. 2) we have the following relation:

$$\cot \tfrac{1}{2}(\xi + \xi') = \tan \tfrac{1}{2}\, d\,M \frac{\cos \frac{1}{2}(\lambda + \lambda')}{\cos \frac{1}{2}(\lambda' - \lambda)} = \tan \tfrac{1}{2}\, d\,M \frac{\sin \frac{1}{2}(L + L')}{\cos \frac{1}{2}(L' - L)}$$

but—

$$\xi = 180^\circ - Z$$

therefore—

$$\cot \tfrac{1}{2}(180^\circ - Z + \xi') = -\tan \tfrac{1}{2}(\xi' - Z)$$

or—

$$-\tan \tfrac{1}{2}(d\,Z) = \tan \tfrac{1}{2}(d\,M) \frac{\sin \frac{1}{2}(L + L')}{\cos \frac{1}{2}(L' - L)}$$

Assuming the tangents of $\frac{1}{2}\,d\,Z$ and $\frac{1}{2}\,d\,M$ proportional to their arcs, and writing λ for the middle latitude, we have—

$$-d\,Z = d\,M \frac{\sin \lambda}{\cos \frac{1}{2}\,d\,L} \tag{4}$$

and—

$$Z' = Z + 180^\circ + d\,Z$$

When the difference of longitude is very large, it may be necessary to correct for the error in the assumption that $\tan \frac{1}{2}\,d\,Z : \tan \frac{1}{2}\,d\,M = d\,Z : d\,M$. By an obvious transformation, we find the correction to be $+ \frac{1}{12}\,d\,M^3 \sin \lambda \cos^2 \lambda \sin^2 1''$, for which we write $+ d\,M^3\,F$, where F is to be taken from a special table, given on page 366. This term is only 0″.01 when log $d\,M = 3.36$ and need never be used for secondary triangulation. A convenient table for finding $\cos \frac{1}{2}\,d\,L$ is given on page 365.

The tables are based upon the supposition that the earth is a spheroid of revolution, having its equatorial semi-diameter—

$$a = 6\;377\;397.2 \text{ metres}$$

its polar semi-diameter—

$$b = 6\;356\;079.0 \text{ metres}$$

and, consequently—

$$a : b = 299.153 : 298.153$$

as derived by Bessel, in *Astronom. Nachrichten*, Nos. 333 and 438, 1834, from the arcs measured up to that time. All geodetic computations hitherto made in the Coast Survey have been based upon those elements. Very considerable additions have, however, since been made to our knowledge of the figure and magnitude of the earth. Their latest combination is that made by Col. A. R. Clarke, R. E., of the British Ordnance Survey, and published in "Comparisons of Standards of Length, made at the Ordnance Office, Southampton, 1866." He finds—

$$a = 6\;378\;206.4 \text{ metres}$$

$$b = 6\;356\;583.8 \text{ metres}$$

consequently—

$$a : b = 294.98 : 293.98$$

He also finds, by elaborate comparisons, that—

$$1 \text{ metre} = 39.370432 \text{ inches}$$

which may well be taken as the most accurate value now known.

The tables of the factors A, B, C, D, E, may be readily conformed to the Clarke spheroid by applying the corrections given on pp. 366 and 367; and differences of latitude and longitude may at once be transformed to the same by the use of the subsequent table.

The following examples will further illustrate the use of the formulæ and tables.

L. M. Z.—FORM FOR PRIMARY TRIANGULATION.

		°	′	″
Z	Mount Blue to Mount Pleasant	26	19	27.01
∠	Mount Pleasant and Ragged	−85	35	25.67
Z	Mount Blue to Ragged	300	44	01.34
dZ		+	50	04.21
180		180		
Z′	Ragged to Mount Blue	121	34	05.55

	°	′	″			°	′	″
L	44	43	40.121	Mount Blue.	M	70	20	11.921
dL	—	30	56.166	110740.6 metres (68.8 miles, nearly).	dM	— 1	11	28.343
L′	44	12	43.955	Ragged.	M′	69	08	43.578

K	5.0443070	K²	10.08861	(δ L²)	6.5373	h	3.2633
cos Z	9.7084622	Sin² Z	9.86854	D	2.3872	K² sin² Z	9.9571
B	8.5105331	C	1.40002			E	6.2070
h	3.2633023		1.35717		8.9245		9.4274
1st term	″ +1833.590	3d term.	+ 0.084			dM³	10.897$_n$
2d term	22.760	—4th term.	— 0.268			F	7.840
	+1856.350						8.737$_n$
3d and 4th terms	− 0.184						
—dL	+1856.166			Arg.		dM	3.632289$_n$
λ	44° 28′ 12″.0	K	5.0443070	K	— 218	sin λ	9.845430
		sin Z	9.9342721$_n$	dM	+ 314	cos ½ dL ar. co.	0.000004
		A′	8.5090758				
		cos L′ ar. co.	0.1446250				3.477723$_n$
			3.6322895$_n$	corr.	+ 96	—dZ	″ —3004.16
		dM	—4288″.343			2d term.	— 0.05

L. M. Z.—FORM FOR SECONDARY TRIANGULATION.

		°	′	″
Z	Tomales Bay to Sonoma	244	08	27.3
∠	Sonoma and Bodega	−83	14	36.8
Z	Tomales Bay to Bodega	160	53	50.5
d Z		—	2	02.0
180		180		
Z′	Bodega to Tomales Bay	340	51	48.5

	°	′	″			°	′	″
L	38	10	52.524	Tomales Bay.	M	122	55	48.380
d L	+	7	28.257	14626.8 metres.	d M	+	3	17.040
L′	38	18	20.781	Bodega.	M′	122	59	05.420

λ = 38° 14′ 37″		K	4.1651480	K²	8.33030		
		cos Z	9.9754014$_n$	sin² Z	9.02979	h^2	5.3031
		B	8.5110266	C	1.30044	D	2.3743
	″						
1st term	−448.308	h	2.6515760$_n$		8.66053		7.6774
2d & 3d term	+ 0.051				0.046		0.005
−d L	−448.257	K	4.1651480				
		sin Z	9.5148949				
		A′	8.5092241	d M	2.29456		
		cos L′ Ar. comp.	0.1052885	sin λ	9.79169		
			2.2945555		2.08625		
			″		″		
		d M	+197.040	−d Z	+122.0		

THE INVERSE PROBLEM.—There are cases when it is required to compute the distance and azimuth between two points that are given by their latitudes and longitudes. This problem is of comparatively rare occurrence, and it has not been found necessary to construct special formulæ and blank forms for it since it can readily be solved by using those provided for the case heretofore treated. This is done by dividing $d\,M = K \sin Z \,.\, A'$ by the first term for $d\,L$, $h = K \cos Z \,.\, B$, when we get, $\tan Z = \frac{d\,M}{h} \cdot \frac{B}{A'}$, which would give us the azimuth at once if we knew h, $d\,M$ being given. We therefore seek to compute the smaller terms for the difference of latitude, in order to obtain h by subtracting them from the known $d\,L$. The only addition to the usual form is the term, $\log \tan Z = \log (K \sin Z) - \log (K \cos Z)$. K will best be taken from the term h when sin Z is greater than cos Z, and from the term $d\,M$ when the reverse is the case. When the distance K is large, as in primary triangulation, it will be necessary to introduce the correction for $d\,M$ due to difference of ratio between sine and arc, using the form for primary L. M. Z. inversely, as indicated above.

L. M. Z.—FORM FOR INVERSE SOLUTION.

		°	'	"
Z	—— to ——			
∠	—— and ——			
Z	Tomales Bay to Bodega	160	53	50.5
dZ		—	02	02.0
180°		180		
Z'	Bodega to Tomales Bay	340	51	48.5

	°	'	"			°	'	"
L	38	10	52.524	Tomales Bay.	M	122	55	48.380
dL	+	7	28.257		dM	+	3	17.040
L'	38	18	20.781	Bodega.	M'	122	59	05.420

$\lambda = 38°\ 14'\ 37''$		K		K^2	7.36008		
		cos Z		$\sin^2 Z$		h^2	5.3031
		B	8.5110266	C	1.30044	D	2.3743
1st term	" −448.308	h	2.6515760_n		8.66052		7.6774
2d and 3d terms	+0.051				0.0458		0.0048
−dL	−448.257	K				K sin Z	3.6800429
		sin Z				K cos Z	4.1405494_n
		A'	8.5092241	dM	2.29456	tan Z	9.5394935_n
8.6145126		cos L' ar comp.	0.1052885	sin λ	9.79169	Z	160° 53' 50".5
			2.2945555		2.08625	sin Z	9.5148949
			"		"	K	4.1651480
		dM	+197.040	−dZ	+122.0		

LATITUDE 23°

Lat.	log A diff. 1″=−0.05	log B diff. 1″=−0.15	log C diff. 1″=+0.58	log D diff. 1″=+0.04	log E diff. 1″=+0.04
° ′					
23 00	8.5095603	8.5120259	1.03398	2.2426	5.7998
1	00	50	433	29	5.8000
2	8.5095597	40	468	31	03
3	94	31	503	34	05
4	91	22	538	36	08
5	88	13	573	39	10
6	85	04	608	41	13
7	82	8.5120195	643	43	15
8	78	86	677	46	18
9	75	77	712	48	20
10	8.5095572	8.5120167	1.03747	2.2451	5.8023
11	69	58	782	53	25
12	66	49	817	56	27
13	63	40	851	58	30
14	60	31	886	60	32
15	57	22	921	63	35
16	54	12	956	65	37
17	51	03	990	68	40
18	48	8.5120094	1.04025	70	42
19	45	85	060	72	45
20	8.5095542	8.5120076	1.04094	2.2475	5.8047
21	39	66	129	77	50
22	36	57	163	80	52
23	33	48	198	82	55
24	29	39	232	84	57
25	26	29	267	87	60
26	23	20	302	89	62
27	20	11	336	91	65
28	17	02	371	94	67
29	14	8.5119993	405	96	70
30	8.5095511	8.5119983	1.04440	2.2499	5.8072
31	08	74	474	2.2501	75
32	05	65	508	03	77
33	02	55	543	06	80
34	8.5095499	46	577	08	82
35	96	37	611	10	85
36	92	28	646	13	87
37	89	18	680	15	90
38	86	09	714	17	92
39	83	00	749	20	95
40	8.5095480	8.5119890	1.04783	2.2522	5.8097
41	77	81	817	24	5.8100
42	74	72	851	27	02
43	71	62	885	29	05
44	68	53	919	31	07
45	64	44	954	34	10
46	61	34	988	36	12
47	58	25	1.05022	38	15
48	55	16	056	41	17
49	52	06	090	43	20
50	8.5095449	8.5119797	1.05124	2.2545	5.8122
51	46	88	158	48	25
52	43	78	192	50	27
53	40	69	226	52	30
54	36	60	260	55	32
55	33	50	294	57	35
56	30	41	328	59	37
57	27	31	362	61	40
58	24	22	396	64	42
59	21	13	430	66	45
60	8.5095418	8.5119703	1.05464	2.2568	5.8148

LATITUDE 24°

Lat.	log **A** diff. 1″=−0.05	log **B** diff. 1″=−0.16	log **C** diff. 1″=+0.56	log **D** diff. 1″=+0.04	log **E** diff. 1″=+0.04
° ′					
24 00	8.5095418	8.5119703	1.05464	2.2568	5.8148
1	15	8.5119694	498	71	50
2	11	84	532	73	53
3	08	75	565	75	55
4	05	65	599	77	58
5	02	56	633	80	60
6	8.5095399	47	667	82	63
7	96	37	700	84	65
8	92	28	734	87	68
9	89	18	768	89	70
10	8.5095386	8.5119609	1.05802	2.2591	5.8173
11	83	8.5119599	835	93	75
12	80	90	869	96	78
13	77	80	903	98	81
14	74	71	936	2.2600	83
15	70	61	970	02	86
16	67	52	1.06003	05	88
17	64	43	037	07	91
18	61	33	071	09	93
19	58	24	104	11	96
20	8.5095355	8.5119514	1.06138	2.2614	5.8198
21	51	05	171	16	5.8201
22	48	8.5119495	205	18	03
23	45	85	238	20	06
24	42	76	272	23	09
25	39	66	305	25	11
26	36	57	339	27	14
27	32	47	372	29	16
28	29	38	405	31	19
29	26	28	439	33	21
30	8.5095323	8.5119419	1.06472	2.2636	5.8224
31	20	09	506	38	27
32	16	00	539	40	29
33	13	8.5119390	572	42	32
34	10	80	605	44	34
35	07	71	639	47	37
36	04	61	672	49	39
37	00	52	705	51	42
38	8.5095297	42	738	53	44
39	94	33	772	55	47
40	8.5095291	8.5119323	1.06805	2.2658	5.8250
41	88	13	838	60	52
42	84	04	871	62	55
43	81	8.5119294	904	64	57
44	78	84	937	66	60
45	75	75	970	68	63
46	72	65	1.07004	71	65
47	68	56	037	73	68
48	65	46	070	75	70
49	62	36	103	77	73
50	8.5095259	8.5119227	1.07136	2.2679	5.8275
51	56	17	169	81	78
52	52	07	202	84	81
53	49	8.5119198	235	86	83
54	46	88	268	88	86
55	43	78	301	90	88
56	39	69	334	92	91
57	36	59	366	94	94
58	33	49	399	96	96
59	30	40	432	99	99
60	8.5095227	8.5119130	1.07465	2.2701	5.8301

LATITUDE 25°

Lat.	log **A** diff. 1″=−0.06	log **B** diff. 1″=−0.16	log **C** diff. 1″=+0.54	log **D** diff. 1″=+0.03	log **E** diff. 1″=+0.04
° ′					
25 00	8.5095227	8.5119130	1.07465	2.2701	5.8301
1	23	20	498	03	04
2	20	10	531	05	07
3	17	01	564	07	09
4	14	8.5119091	596	09	12
5	10	81	629	11	14
6	07	72	662	13	17
7	04	62	695	16	20
8	01	52	728	18	22
9	8.5095197	42	760	20	25
10	8.5095194	8.5119033	1.07793	2.2722	5.8327
11	91	23	826	24	30
12	88	13	858	26	33
13	84	03	891	28	35
14	81	8.5118994	924	30	38
15	78	84	956	32	40
16	75	74	989	34	43
17	71	64	1.08021	37	46
18	68	55	054	39	48
19	65	45	087	41	51
20	8.5095162	8.5118935	1.08119	2.2743	5.8354
21	58	25	152	45	56
22	55	15	184	47	59
23	52	05	217	49	61
24	48	8.5118896	249	51	64
25	45	86	282	53	67
26	42	76	314	55	69
27	39	66	346	57	72
28	35	56	379	59	75
29	32	47	411	61	77
30	8.5095129	8.5118837	1.08444	2.2763	5.8380
31	26	27	476	66	82
32	22	17	508	68	85
33	19	07	541	70	88
34	16	8.5118797	573	72	90
35	12	87	605	74	93
36	09	78	638	76	96
37	06	68	670	78	98
38	03	58	702	80	5.8401
39	8.5095099	48	734	82	04
40	8.5095096	8.5118738	1.08767	2.2784	5.8406
41	93	28	799	86	09
42	89	18	831	88	11
43	86	08	863	90	14
44	83	8.5118698	895	92	17
45	79	89	928	94	19
46	76	79	960	96	22
47	73	69	992	98	25
48	70	59	1.09024	2.2800	27
49	66	49	056	02	30
50	8.5095063	8.5118639	1.09088	2.2804	5.8433
51	60	29	120	06	35
52	56	19	152	08	38
53	53	09	184	10	41
54	50	8.5118599	217	12	43
55	46	89	249	14	46
56	43	79	281	16	49
57	40	69	312	18	51
58	36	59	344	20	54
59	33	49	376	22	57
60	8.5095030	8.5118539	1.09408	2.2824	5.8459

LATITUDE 26°

Lat.	log **A** diff. 1″=−0.06	log **B** diff. 1″=−0.17	log **C** diff. 1″=+0.53	log **D** diff. 1″=+0.03	log **E** diff. 1″=+0.04
° ′					
26 00	8.5095030	8.5118539	1.09408	2.2824	5.8459
1	26	29	440	26	62
2	23	19	472	28	65
3	20	09	504	30	67
4	16	8.5118499	536	32	70
5	13	89	568	34	73
6	10	79	600	36	75
7	06	69	631	38	78
8	03	59	663	40	81
9	8.5095000	49	695	42	83
10	8.5094996	8.5118439	1.09727	2.2844	5.8486
11	93	29	759	46	89
12	90	19	790	48	91
13	86	09	822	50	94
14	83	8.5118399	854	52	97
15	80	89	886	54	99
16	76	79	917	55	5.8502
17	73	69	949	57	05
18	70	59	981	59	07
19	66	49	1.10012	61	10
20	8.5094963	8.5118339	1.10044	2.2863	5.8513
21	60	29	076	65	15
22	56	19	107	67	18
23	53	09	139	69	21
24	49	8.5118299	170	71	24
25	46	88	202	73	26
26	43	78	234	75	29
27	39	68	265	77	32
28	36	58	297	79	34
29	33	48	328	81	37
30	8.5094929	8.5118238	1.10360	2.2883	5.8540
31	26	28	391	84	42
32	22	18	423	86	45
33	19	08	454	88	48
34	16	8.5118197	486	90	50
35	12	87	517	92	53
36	09	77	548	94	56
37	06	67	580	96	59
38	02	57	611	98	61
39	8.5094899	47	643	2.2900	64
40	8.5094895	8.5118137	1.10674	2.2902	5.8567
41	92	26	705	03	69
42	89	16	737	05	72
43	85	06	768	07	75
44	82	8.5118096	799	09	77
45	78	86	831	11	80
46	75	76	862	13	83
47	72	65	893	15	86
48	68	55	924	17	88
49	65	45	956	18	91
50	8.5094862	8.5118035	1.10987	2.2920	5.8594
51	58	25	1.11018	22	96
52	55	14	049	24	99
53	51	04	081	26	5.8602
54	48	8.5117994	112	28	05
55	45	84	143	30	07
56	41	74	174	32	10
57	38	63	205	33	13
58	34	53	236	35	16
59	31	43	268	37	18
60	8.5094827	8.5117933	1.11299	2.2939	5.8621

LATITUDE 27°

Lat.	log A	log B	log C	log D	log E
	diff. $1'' = -0.06$	diff. $1'' = -0.17$	diff. $1'' = +0.51$	diff. $1'' = +0.03$	diff. $1'' = +0.05$
° '					
27 00	8.5094827	8.5117933	1.11299	2.2939	5.8621
1	24	22	330	41	24
2	21	12	361	43	26
3	17	02	392	44	29
4	14	8.5117892	423	46	32
5	10	81	454	48	35
6	07	71	485	50	37
7	04	61	516	52	40
8	00	50	547	54	43
9	8.5094797	40	578	55	46
10	8.5094793	8.5117830	1.11609	2.2957	5.8648
11	90	20	640	59	51
12	86	09	671	61	54
13	83	8.5117799	702	63	57
14	79	89	733	65	59
15	76	78	764	66	62
16	73	68	794	68	65
17	69	58	825	70	68
18	66	47	856	72	70
19	62	37	887	74	73
20	8.5094759	8.5117727	1.11918	2.2975	5.8676
21	55	16	949	77	78
22	52	06	979	79	81
23	48	8.5117696	1.12010	81	84
24	45	85	041	83	87
25	42	75	072	84	90
26	38	65	103	86	92
27	35	54	133	88	95
28	31	44	164	90	98
29	28	34	195	92	5.8701
30	8.5094724	8.5117623	1.12226	2.2993	5.8703
31	21	13	256	95	06
32	17	02	287	97	09
33	14	8.5117592	318	99	12
34	10	82	348	2.3000	14
35	07	71	379	02	17
36	03	61	410	04	20
37	00	50	440	06	23
38	8.5094697	40	471	07	25
39	93	30	501	09	28
40	8.5094690	8.5117519	1.12532	2.3011	5.8731
41	86	09	563	13	34
42	83	8.5117498	593	15	36
43	79	88	624	16	39
44	76	78	654	18	42
45	72	67	685	20	45
46	69	57	715	21	48
47	65	46	746	23	50
48	62	36	776	25	53
49	58	25	807	27	56
50	8.5094655	8.5117415	1.12837	2.3028	5.8759
51	51	04	868	30	61
52	48	8.5117394	898	32	64
53	44	83	928	34	67
54	41	73	959	35	70
55	37	63	989	37	73
56	34	52	1.13020	39	75
57	30	42	050	41	78
58	27	31	080	42	81
59	23	21	111	44	84
60	8.5094620	8.5117310	1.13141	2.3046	5.8787

LATITUDE 28°

Lat.	log **A** diff. 1″=−0.06	log **B** diff. 1″=−0.18	log **C** diff. 1″=+0.50	log **D** diff. 1″=+0.03	log **E** diff. 1″=+0.05
° ′					
28 00	8.5094620	8.5117310	1.13141	2.3046	5.8787
1	16	00	171	47	89
2	13	8.5117289	202	49	92
3	09	79	232	51	95
4	06	68	262	53	98
5	02	58	293	54	5.8800
6	8.5094599	47	323	56	03
7	95	36	353	58	06
8	92	26	383	59	09
9	88	15	414	61	12
10	8.5094585	8.5117205	1.13444	2.3063	5.8814
11	81	8.5117194	474	64	17
12	78	84	504	66	20
13	74	73	535	68	23
14	71	63	565	70	26
15	67	52	595	71	28
16	64	42	625	73	31
17	60	31	655	75	34
18	57	20	685	76	37
19	53	10	715	78	40
20	8.5094550	8.5117099	1.13746	2.3080	5.8843
21	46	89	776	81	45
22	43	78	806	83	48
23	39	67	836	85	51
24	36	57	866	86	54
25	32	46	896	88	57
26	28	36	926	90	59
27	25	25	956	91	62
28	21	14	986	93	65
29	18	04	1.14016	95	68
30	8.5094514	8.5116993	1.14046	2.3096	5.8871
31	11	83	076	98	74
32	07	72	106	2.3100	76
33	04	61	136	01	79
34	00	51	166	03	82
35	8.5094497	40	196	04	85
36	93	29	226	06	88
37	90	19	256	08	90
38	86	08	285	09	93
39	82	8.5116897	315	11	96
40	8.5094479	8.5116887	1.14345	2.3113	5.8899
41	75	76	375	14	5.8902
42	72	65	405	16	05
43	68	55	435	17	07
44	65	44	465	19	10
45	61	33	494	21	13
46	57	23	524	22	16
47	54	12	554	24	19
48	50	01	584	26	22
49	47	8.5116791	614	27	24
50	8.5094443	8.5116780	1.14643	2.3129	5.8927
51	40	69	673	30	30
52	36	59	703	32	33
53	33	48	733	34	36
54	29	37	762	35	39
55	25	26	792	37	42
56	22	16	822	38	44
57	18	05	851	40	47
58	15	8.5116694	881	42	50
59	11	83	911	43	53
60	8.5094407	8.5116673	1.14940	2.3145	5.8956

LATITUDE 29°

Lat.	log A diff. 1″=−0.06	log B diff. 1″=—0.18	log C diff. 1″=+0.49	log D diff. 1″=+0.03	log E diff. 1″=+0.05
° ′					
29 00	8.5094407	8.5116673	1.14940	2.3145	5.8956
1	04	62	970	46	59
2	00	51	1.15000	48	61
3	8 5094397	40	029	50	64
4	93	30	059	51	67
5	90	19	089	53	70
6	86	08	118	54	73
7	82	8.5116597	148	56	76
8	79	87	177	57	79
9	75	76	207	59	81
10	8 5094372	8.5116565	1.15236	2.3161	5.8984
11	68	54	266	62	87
12	64	44	295	64	90
13	61	33	325	65	93
14	57	22	354	67	96
15	54	11	384	68	99
16	50	00	413	70	5.9002
17	46	8.5116490	443	72	04
18	43	79	472	73	07
19	39	68	502	75	10
20	8.5094336	8.5116457	1.15531	2.3176	5.9013
21	32	46	561	78	16
22	28	35	590	79	19
23	25	25	620	81	22
24	21	14	649	82	25
25	18	03	678	84	27
26	14	8.5116392	708	85	30
27	10	81	737	87	33
28	07	70	766	89	36
29	03	60	796	90	39
30	8.5094299	8.5116349	1.15825	2.3192	5.9042
31	96	38	854	93	45
32	92	27	884	95	48
33	89	16	913	96	50
34	85	05	942	98	53
35	81	8.5116294	972	99	56
36	78	83	1.16001	2.3201	59
37	74	73	030	02	62
38	70	62	059	04	65
39	67	51	089	05	68
40	8.5094263	8.5116240	1.16118	2.3207	5.9071
41	60	29	147	08	74
42	56	18	176	10	76
43	52	07	206	11	79
44	49	8.5116196	235	13	82
45	45	85	264	14	85
46	41	74	293	16	88
47	38	64	322	17	91
48	34	53	351	19	94
49	30	42	381	20	97
50	8.5094227	8.5116131	1.16410	2.3222	5.9100
51	23	20	439	23	03
52	20	09	468	25	05
53	16	8.5116098	497	26	08
54	12	87	526	28	11
55	09	76	555	29	14
56	05	65	584	31	17
57	01	54	613	32	20
58	8 5094198	43	642	34	23
59	94	32	671	35	26
60	8.5094190	8.5116021	1.16700	2.3237	5.9129

LATITUDE **30°**

Lat.	log **A** diff. 1″=−0.06	log **B** diff. 1″=−0.18	log **C** diff. 1″=+0.48	log **D** diff. 1″=+0.02	log **E** diff. 1″=+0.05
° ′					
30 00	8.5094190	8.5116021	1.16700	2.3237	5.9129
1	87	10	729	38	32
2	83	8.5115999	758	40	34
3	79	88	787	41	37
4	76	77	816	42	40
5	72	66	845	44	43
6	68	55	874	45	46
7	65	44	903	47	49
8	61	33	932	48	52
9	57	22	961	50	55
10	8.5094154	8.5115911	1.16990	2.3251	5.9158
11	50	00	1.17019	53	61
12	46	8.5115889	048	54	64
13	43	78	077	56	67
14	39	67	106	57	69
15	35	56	135	58	72
16	32	45	164	60	75
17	28	34	192	61	78
18	24	23	221	63	81
19	21	12	250	64	84
20	8.5094117	8.5115801	1.17279	2.3266	5.9187
21	13	8.5115790	308	67	90
22	10	79	337	68	93
23	06	68	365	70	96
24	02	57	394	71	99
25	8.5094098	46	423	73	5.9202
26	95	35	452	74	05
27	91	24	481	76	08
28	87	13	509	77	10
29	84	02	538	78	13
30	8.5094080	8.5115690	1.17567	2.3280	5.9216
31	76	79	596	81	19
32	73	68	624	83	22
33	69	57	653	84	25
34	65	46	682	85	28
35	62	35	710	87	31
36	58	24	739	88	34
37	54	13	768	90	37
38	50	02	797	91	40
39	47	8.5115591	825	92	43
40	8.5094043	8.5115579	1.17854	2.3294	5.9246
41	39	68	883	95	49
42	36	57	911	97	52
43	32	46	940	98	55
44	28	35	968	99	58
45	24	24	997	2.3301	61
46	21	13	1.18026	02	64
47	17	02	054	04	66
48	13	8.5115490	083	05	69
49	10	79	111	06	72
50	8.5094006	8.5115468	1.18140	2.3308	5.9275
51	02	57	169	09	78
52	8.5093999	46	197	10	81
53	95	35	226	12	84
54	91	23	254	13	87
55	87	12	283	14	90
56	84	01	311	16	93
57	80	8.5115390	340	17	96
58	76	79	368	19	99
59	72	68	397	20	5.9302
60	8.5093969	8.5115356	1.18425	2.3321	5.9305

LATITUDE 31°

Lat.	log **A**	log **B**	log **C**	log **D**	log **E**
	diff. 1″ = −0.06	diff. 1″ = −0.19	diff. 1″ = +0.47	diff. 1″ = +0.02	diff. 1″ = +0.05
° ′					
31 00	8.5093969	8.5115356	1.18425	2.3321	5.9305
1	65	45	454	23	08
2	61	34	482	24	11
3	58	23	510	25	14
4	54	12	539	27	17
5	50	00	567	28	20
6	46	8.5115289	596	29	23
7	43	78	624	31	26
8	39	67	652	32	29
9	35	56	681	33	32
10	8.5093931	8.5115244	1.18709	2.3335	5.9335
11	28	33	738	36	38
12	24	22	766	37	41
13	20	11	794	39	44
14	16	8.5115199	823	40	47
15	13	88	851	41	50
16	09	77	879	43	53
17	05	66	908	44	56
18	01	54	936	45	59
19	8.5093898	43	964	47	62
20	8.5093894	8.5115132	1.18993	2.3348	5.9365
21	90	21	1.19021	49	68
22	86	09	049	51	71
23	83	8.5115098	077	52	74
24	79	87	106	53	76
25	75	76	134	55	79
26	71	64	162	56	82
27	68	53	190	57	85
28	64	42	219	58	88
29	60	31	247	60	91
30	8.5093856	8.5115019	1.19275	2.3361	5.9394
31	53	08	303	62	97
32	49	8.5114997	331	64	5.9400
33	45	85	360	65	03
34	41	74	388	66	06
35	37	63	416	68	09
36	34	51	444	69	12
37	30	40	472	70	15
38	26	29	501	71	18
39	22	17	529	73	21
40	8.5093819	8.5114906	1.19557	2.3374	5.9424
41	15	8.5114895	585	75	27
42	11	83	613	77	31
43	07	72	641	78	34
44	04	61	669	79	37
45	00	49	697	80	40
46	8.5093796	38	725	82	43
47	92	27	753	83	46
48	88	15	781	84	49
49	85	04	809	85	52
50	8.5093781	8.5114793	1.19838	2.3387	5.9455
51	77	81	866	88	58
52	73	70	894	89	61
53	69	59	922	90	64
54	66	47	950	92	67
55	62	36	978	93	70
56	58	25	1.20006	94	73
57	54	13	034	95	76
58	51	02	062	97	79
59	47	8.5114690	090	98	82
60	8.5093743	8.5114679	1.20118	2.3399	5.9485

LATITUDE 32°

Lat.	log **A** diff. 1″=−0.06	log **B** diff. 1″=−0.19	log **C** diff. 1″=+0.46	log **D** diff. 1″=+0.02	log **E** diff. 1″=+0.05
° ′					
32 00	8.5093743	8.5114679	1.20118	2.3399	5.9485
1	39	68	145	2.3400	88
2	35	56	173	02	91
3	32	45	201	03	94
4	28	33	229	04	97
5	24	22	257	05	5.9500
6	20	11	285	07	03
7	16	8.5114599	313	08	06
8	13	88	341	09	09
9	09	76	369	10	12
10	8.5093705	8.5114565	1.20397	2.3412	5.9515
11	01	54	425	13	18
12	8.5093697	42	452	14	21
13	93	31	480	15	24
14	90	19	508	16	27
15	86	08	536	18	30
16	82	8.5114496	564	19	33
17	78	85	592	20	36
18	74	74	620	21	39
19	71	62	647	23	42
20	8.5093667	8.5114451	1.20675	2.3424	5.9545
21	63	39	703	25	49
22	59	28	731	26	52
23	55	16	759	27	55
24	51	05	786	29	58
25	48	8.5114393	814	30	61
26	44	82	842	31	64
27	40	70	870	32	67
28	36	59	897	33	70
29	32	47	925	35	73
30	8.5093629	8.5114336	1.20953	2.3436	5.9576
31	25	24	981	37	79
32	21	13	1.21008	38	82
33	17	01	036	39	85
34	13	8.5114290	064	40	88
35	09	78	091	42	91
36	06	67	119	43	94
37	02	55	147	44	97
38	8.5093598	44	174	45	5.9600
39	94	32	202	46	04
40	8.5093590	8.5114221	1.21230	2.3448	5.9607
41	86	09	257	49	10
42	83	8.5114198	285	50	13
43	79	86	312	51	16
44	75	75	340	52	19
45	71	63	368	53	22
46	67	52	395	54	25
47	63	40	423	56	28
48	59	29	451	57	31
49	56	17	478	58	34
50	8.5093552	8.5114106	1.21506	2.3459	5.9637
51	48	8.5114094	533	60	40
52	44	83	561	61	43
53	40	71	588	63	46
54	36	59	616	64	50
55	33	48	644	65	53
56	29	36	671	66	56
57	25	25	699	67	59
58	21	13	726	68	62
59	17	02	754	69	65
60	8.5093513	8.5113990	1.21781	2.3471	5.9668

LATITUDE 33°

Lat.	log **A** diff. 1″=−0.06	log **B** diff. 1″=−0.19	log **C** diff. 1″=+0.45	log **D** diff. 1″=+0.02	log **E** diff. 1″=+0.05
° ′					
33 00	8.5093513	8.5113990	1.21781	2.3471	5.9668
1	09	78	809	72	71
2	06	67	836	73	74
3	02	55	864	74	77
4	8.5093498	44	891	75	80
5	94	32	919	76	83
6	90	20	946	77	87
7	86	09	973	79	90
8	82	8.5113897	1.22001	80	93
9	79	86	028	81	96
10	8.5093475	8.5113874	1.22056	2.3482	5.9699
11	71	62	083	83	5.9702
12	67	51	111	84	05
13	63	39	138	85	08
14	59	28	165	86	11
15	55	16	193	87	14
16	51	04	220	89	17
17	47	8.5113793	248	90	21
18	44	81	275	91	24
19	40	69	303	92	27
20	8.5093436	8.5113758	1.22330	2.3493	5.9730
21	32	46	357	94	33
22	28	35	385	95	36
23	24	23	412	96	39
24	20	11	439	97	42
25	16	00	467	98	45
26	13	8.5113688	494	2.3500	48
27	09	76	521	01	52
28	05	65	549	02	55
29	01	53	576	03	58
30	8.5093397	8.5113641	1.22603	2.3504	5.9761
31	93	30	630	05	64
32	89	18	658	06	67
33	85	06	685	07	70
34	81	8.5113595	712	08	73
35	78	83	739	09	76
36	74	71	767	10	80
37	70	60	794	11	83
38	66	48	821	13	86
39	62	36	848	14	89
40	8.5093358	8.5113525	1.22876	2.3515	5.9792
41	54	13	903	16	95
42	50	01	930	17	98
43	46	8.5113489	957	18	5.9801
44	42	78	984	19	05
45	39	66	1.23012	20	08
46	35	54	039	21	11
47	31	43	066	22	14
48	27	31	093	23	17
49	23	19	120	24	20
50	8.5093319	8.5113407	1.23148	2.3525	5.9823
51	15	8.5113396	175	26	26
52	11	84	202	27	30
53	07	72	229	28	33
54	03	60	256	29	36
55	00	49	283	30	39
56	8.5093296	37	310	32	42
57	92	25	337	33	45
58	88	14	305	34	48
59	84	02	392	35	51
60	8.5093280	8.5113290	1.23419	2.3536	5.9855

LATITUDE 34°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.20	log **C** diff. 1″=+0.45	log **D** diff. 1″=+0.02	log **E** diff. 1″=+0.05
° ′					
34 00	8.5093280	8.5113290	1.23419	2.3536	5.9855
1	76	78	446	37	58
2	72	67	473	38	61
3	68	55	500	39	64
4	64	43	527	40	67
5	60	31	554	41	70
6	56	19	581	42	73
7	53	08	608	43	77
8	49	8.5113196	635	44	80
9	45	84	662	45	83
10	8.5093241	8.5113172	1.23689	2.3546	5.9886
11	37	61	716	47	89
12	33	49	743	48	92
13	29	37	770	49	95
14	25	25	797	50	99
15	21	13	824	51	5.9902
16	17	02	851	52	05
17	13	8.5113090	878	53	08
18	09	78	905	54	11
19	05	66	932	55	14
20	8.5093201	8.5113055	1.23959	2.3556	5.9918
21	8.5093198	43	986	57	21
22	94	31	1.24013	58	24
23	90	19	040	59	27
24	86	07	067	60	30
25	82	8.5112995	094	61	33
26	78	84	121	62	36
27	74	72	148	63	40
28	70	60	175	64	43
29	66	48	202	65	46
30	8.5093162	8.5112936	1.24229	2.3566	5.9949
31	58	24	256	67	52
32	54	13	283	68	55
33	50	01	309	69	59
34	46	8.5112889	336	70	62
35	42	77	363	71	65
36	38	65	390	72	68
37	34	53	417	73	71
38	30	42	444	74	75
39	27	30	471	75	78
40	8.5093123	8.5112818	1.24498	2.3576	5.9981
41	19	06	524	77	84
42	15	8.5112794	551	78	87
43	11	82	578	78	90
44	07	70	605	79	94
45	03	58	632	80	97
46	8.5093099	47	659	81	6.0000
47	95	35	685	82	03
48	91	23	712	83	06
49	87	11	739	84	09
50	8.5093083	8.5112699	1.24766	2.3585	~~5~~.0013 6
51	79	87	793	86	16
52	75	75	819	87	19
53	71	63	846	88	22
54	67	52	873	89	25
55	63	40	900	90	29
56	59	28	926	91	32
57	55	16	953	92	35
58	51	04	980	93	38
59	47	8.5112592	1.25007	94	41
60	8.5093043	8.5112580	1.25033	2.3595	6.0045

LATITUDE 35°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.20	log **C** diff. 1″=+0.44	log **D** diff. 1″=+0.01	log **E** diff. 1″=+0.05
° ′					
35 00	8.5093043	8.5112580	1.25033	2.3595	6.0045
1	39	68	060	96	48
2	35	56	087	96	51
3	31	44	113	97	54
4	27	32	140	98	57
5	23	21	167	99	61
6	19	09	194	2.3600	64
7	15	8.5112497	220	01	67
8	12	85	247	02	70
9	08	73	274	03	73
10	8.5093004	8.5112461	1.25300	2.3604	6.0077
11	00	49	327	05	80
12	8.5092996	37	354	06	83
13	92	25	380	07	86
14	88	13	407	07	89
15	84	01	434	08	93
16	80	8.5112389	460	09	96
17	76	77	487	10	99
18	72	65	514	11	6.0102
19	68	53	540	12	05
20	8.5092964	8.5112341	1.25567	2.3613	6.0109
21	60	29	593	14	12
22	56	17	620	15	15
23	52	06	647	16	18
24	48	8.5112294	673	16	21
25	44	82	700	17	25
26	40	70	726	18	28
27	36	58	753	19	31
28	32	46	779	20	34
29	28	34	806	21	38
30	8.5092924	8.5112222	1.25833	2.3622	6.0141
31	20	10	859	23	44
32	16	8.5112198	886	24	47
33	12	86	912	24	50
34	08	74	939	25	54
35	04	62	965	26	57
36	00	50	992	27	60
37	8.5092896	38	1.26018	28	63
38	92	26	045	29	67
39	88	14	072	30	70
40	8.5092884	8.5112102	1.26098	2.3631	6.0173
41	80	8.5112090	125	31	76
42	76	78	151	32	79
43	72	66	177	33	83
44	68	54	204	34	86
45	64	42	230	35	89
46	60	30	257	36	92
47	56	18	283	37	96
48	52	06	310	37	99
49	48	8.5111994	336	38	6.0202
50	8.5092844	8.5111981	1.26363	2.3639	6.0205
51	40	69	389	40	09
52	36	57	416	41	12
53	32	45	442	42	15
54	28	33	469	42	18
55	24	21	495	43	22
56	20	09	521	44	25
57	16	8.5111897	548	45	28
58	12	85	574	46	31
59	08	73	601	47	35
60	8.5092804	8.5111861	1.26627	2.3648	6.0238

LATITUDE 36°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.20	log **C** diff. 1″=+0.44	log **D** diff. 1″=+0.01	log **E** diff. 1″=+0.05
° ′					
36 00	8.5092804	8.5111861	1.26627	2.3648	6.0238
1	00	49	654	48	41
2	8.5092796	37	680	49	44
3	92	25	706	50	48
4	88	13	733	51	51
5	83	01	759	52	54
6	79	8.5111789	785	52	57
7	75	77	812	53	61
8	71	65	838	54	64
9	67	52	865	55	67
10	8.5092763	8.5111740	1.26891	2.3656	6.0270
11	59	28	917	57	74
12	55	16	944	57	77
13	51	04	970	58	80
14	47	8.5111692	996	59	83
15	43	80	1.27023	60	87
16	39	68	049	61	90
17	35	56	075	61	93
18	31	44	102	62	96
19	27	32	128	63	6.0300
20	8.5092723	8.5111619	1.27154	2.3664	6.0303
21	19	07	181	65	06
22	15	8.5111595	207	65	09
23	11	83	233	66	13
24	07	71	259	67	16
25	03	59	286	68	19
26	8.5092699	47	312	69	23
27	95	35	338	69	26
28	91	23	365	70	29
29	87	10	391	71	32
30	8.5092683	8.5111498	1.27417	2.3672	6.0336
31	79	86	443	73	39
32	75	74	470	73	42
33	71	62	496	74	45
34	66	50	522	75	49
35	62	38	548	76	52
36	58	26	575	76	55
37	54	13	601	77	59
38	50	01	627	78	62
39	46	8.5111389	653	79	65
40	8.5092642	8.5111377	1.27680	2.3680	6.0368
41	38	65	706	80	72
42	34	53	732	81	75
43	30	41	758	82	78
44	26	28	784	83	82
45	22	16	810	83	85
46	18	04	837	84	88
47	14	8.5111292	863	85	92
48	10	80	889	86	95
49	06	68	915	86	98
50	8.5092602	8.5111255	1.27941	2.3687	6.0401
51	8.5092598	43	968	88	05
52	94	31	994	89	08
53	90	19	1.28020	89	11
54	86	07	046	90	15
55	81	8.5111195	072	91	18
56	77	82	098	92	21
57	73	70	124	92	25
58	69	58	150	93	28
59	65	46	177	94	31
60	8.5092561	8.5111134	1 28203	2.3695	6.0434

LATITUDE 37°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.20	log **C** diff. 1″=+0.43	log **D** diff. 1″=+0.01	log **E** diff. 1″=+0.06
° ′					
37 00	8.5092561	8.5111134	1.28203	2.3695	6.0434
1	57	21	229	95	38
2	53	09	255	96	41
3	49	8.5111097	281	97	44
4	45	85	307	97	48
5	41	73	333	98	51
6	37	60	359	99	54
7	33	48	386	2.3700	58
8	29	36	412	00	61
9	25	24	438	01	64
10	8.5092520	8.5111012	1.28464	2.3702	6.0467
11	16	8.5110999	490	03	71
12	12	87	516	03	74
13	08	75	542	04	77
14	04	63	568	05	81
15	00	51	594	05	84
16	8.5092496	38	620	06	87
17	92	26	646	07	91
18	88	14	672	08	94
19	84	02	698	08	97
20	8.5092480	8.5110890	1.28724	2.3709	6.0501
21	76	77	750	10	04
22	72	65	776	10	07
23	68	53	802	11	11
24	63	41	828	12	14
25	59	28	855	12	17
26	55	16	881	13	21
27	51	04	907	14	24
28	47	8.5110792	933	15	27
29	43	79	959	15	31
30	8.5092439	8.5110767	1.28985	2.3716	6.0534
31	35	55	1.29011	17	37
32	31	43	036	17	41
33	27	30	062	18	44
34	23	18	088	19	47
35	19	06	114	19	51
36	14	8.5110694	140	20	54
37	10	81	166	21	57
38	06	69	192	21	61
39	02	57	218	22	64
40	8.5092398	8.5110645	1.29244	2.3723	6.0567
41	94	32	270	23	71
42	90	20	296	24	74
43	86	08	322	25	77
44	82	8.5110595	348	25	81
45	78	83	374	26	84
46	74	71	400	27	87
47	69	59	426	27	91
48	65	46	452	28	94
49	61	34	478	29	97
50	8.5092357	8.5110522	1.29504	2.3729	6.0601
51	53	10	530	30	04
52	49	8.5110497	555	31	07
53	45	85	581	31	11
54	41	73	607	32	14
55	37	60	633	33	18
56	33	48	659	33	21
57	29	36	685	34	24
58	24	23	711	35	28
59	20	11	737	35	31
60	8.5092316	8.5110399	1.29763	2.3736	6.0634

LATITUDE 38°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.21	log **C** diff. 1″=+0.43	log **D** diff. 1″=+0.01	log **E** diff. 1″=+0.06
° ′					
38 00	8.5092316	8.5110399	1.29763	2.3736	6.0634
1	12	87	788	37	38
2	08	74	814	37	41
3	04	62	840	38	44
4	00	50	866	38	48
5	8.5092296	37	892	39	51
6	92	25	918	40	54
7	87	13	944	40	58
8	83	00	969	41	61
9	79	8.5110288	995	42	65
10	8.5092275	8.5110276	1.30021	2.3742	6.0668
11	71	63	047	43	71
12	67	51	073	44	75
13	63	39	099	44	78
14	59	26	124	45	81
15	55	14	150	45	85
16	50	02	176	46	88
17	46	8.5110189	202	47	92
18	42	77	228	47	95
19	38	65	253	48	98
20	8.5092234	8.5110152	1.30279	2.3748	6.0702
21	30	40	305	49	05
22	26	28	331	50	08
23	22	15	357	50	12
24	18	03	382	51	15
25	13	8.5110091	408	52	19
26	09	78	434	52	22
27	05	66	460	53	25
28	01	54	486	53	29
29	8.5092197	41	511	54	32
30	8.5092193	8.5110029	1.30537	2.3755	6.0736
31	89	17	563	55	39
32	85	04	589	56	42
33	81	8.5109992	614	56	46
34	76	80	640	57	49
35	72	67	666	57	52
36	68	55	692	58	56
37	64	42	717	59	59
38	60	30	743	59	63
39	56	18	769	60	66
40	8.5092152	8.5109905	1.30795	2.3760	6.0769
41	48	8.5109893	820	61	73
42	43	81	846	62	76
43	39	68	872	62	80
44	35	56	898	63	83
45	31	43	923	63	86
46	27	31	949	64	90
47	23	19	975	64	93
48	19	06	1.31000	65	97
49	15	8.5109794	026	66	6.0800
50	8.5092110	8.5109782	1.31052	2.3766	6.0803
51	06	69	077	67	07
52	02	57	103	67	10
53	8.5092098	44	129	68	14
54	94	32	155	68	17
55	90	20	180	69	21
56	86	07	206	69	24
57	82	8.5109695	232	70	27
58	77	82	257	71	31
59	73	70	283	71	34
60	8.5092069	8.5109658	1.31309	2.3772	6.0838

LATITUDE 39°

Lat.	log **A** diff. 1″ = −0.07	log **B** diff. 1″ = −0.21	log **C** diff. 1″ = +0.43	log **D** diff. 1″ = +0.01	log **E** diff. 1″ = +0.06
° ′					
39 00	8.5092069	8.5109658	1.31309	2.3772	6.0838
1	65	45	334	2	41
2	61	33	360	3	44
3	57	20	386	3	48
4	53	08	411	4	51
5	48	8.5109596	437	4	55
6	44	83	463	5	58
7	40	71	488	5	62
8	36	58	514	6	65
9	32	46	539	7	68
10	8.5092028	8.5109533	1.31565	2.3777	6.0872
11	24	21	591	8	75
12	19	09	616	8	79
13	15	8.5109496	642	9	82
14	11	84	668	9	86
15	07	71	693	2.3780	89
16	03	59	719	0	92
17	8.5091999	46	744	1	96
18	95	34	770	1	99
19	90	22	796	2	6.0903
20	8.5091986	8.5109409	1.31821	2.3782	6.0906
21	82	8.5109397	847	3	10
22	78	84	872	3	13
23	74	72	898	4	16
24	70	59	924	4	20
25	66	47	949	5	23
26	61	35	975	5	27
27	57	22	1.32000	6	30
28	53	10	026	6	34
29	49	8.5109297	051	7	37
30	8.5091945	8.5109285	1.32077	2.3787	6.0941
31	41	72	103	8	44
32	37	60	128	8	47
33	32	47	154	9	51
34	28	35	179	9	54
35	24	22	205	2.3790	58
36	20	10	230	0	61
37	16	8 5109198	256	1	65
38	12	85	282	1	68
39	07	73	307	2	72
40	8.5091903	8.5109160	1.32333	2.3792	6.0975
41	8.5091899	48	358	3	78
42	95	35	384	3	82
43	91	23	409	4	85
44	87	10	435	4	89
45	83	8.5109098	460	5	92
46	78	85	486	5	96
47	74	73	512	6	99
48	70	60	537	6	6.1003
49	66	48	563	7	06
50	8.5091862	8 5109036	1.32588	2.3797	6.1010
51	58	23	614	8	13
52	53	11	639	8	17
53	49	8.5108998	665	9	20
54	45	86	690	9	24
55	41	73	716	2.3800	27
56	37	61	741	0	30
57	33	48	767	1	34
58	28	36	792	1	37
59	24	23	818	1	41
60	8.5091820	8.5108911	1.32843	2.3802	6.1044

LATITUDE 40°

Lat.	log **A**	log **B**	log **C**	log **D**	log **E**
	diff. 1″=−0.07	diff. 1″=−0.21	diff. 1″=+0.42	diff. 1″=+0.01	diff. 1″=+0.06
° ′					
40 00	8.5091820	8.5108911	1.32843	2.3802	6.1044
1	16	8.5108898	869	2	48
2	12	86	894	3	51
3	08	73	920	3	55
4	03	61	945	4	58
5	8.5091799	48	970	4	62
6	95	36	996	5	65
7	91	23	1.33021	5	69
8	87	11	047	6	72
9	83	8.5108798	072	6	76
10	8.5091778	8.5108786	1.33098	2 3806	6.1079
11	74	73	123	7	83
12	70	61	149	7	86
13	66	48	174	8	90
14	62	36	200	8	93
15	58	23	225	9	97
16	53	11	251	9	6.1100
17	49	8.5108698	276	9	04
18	45	86	301	2.3810	07
19	41	73	327	0	11
20	8.5091737	8.5108661	1.33352	2.3811	6.1114
21	33	48	378	1	18
22	28	36	403	2	21
23	24	23	429	2	25
24	20	11	454	2	28
25	16	8.5108598	480	3	32
26	12	85	505	3	35
27	08	73	530	4	39
28	03	60	556	4	42
29	8.5091699	48	581	5	46
30	8.5091695	8.5108535	1.33607	2.3815	6.1149
31	91	23	632	5	53
32	87	10	657	6	56
33	83	8.5108498	683	6	60
34	78	85	708	7	63
35	74	73	734	7	67
36	70	60	759	7	70
37	66	48	784	8	74
38	62	35	810	8	77
39	57	23	835	9	81
40	8.5091653	8.5108410	1.33861	2.3819	6.1184
41	49	8.5108398	886	9	88
42	45	85	911	2.3820	91
43	41	72	937	0	95
44	37	60	962	1	98
45	32	47	987	1	6.1202
46	28	35	1.34013	1	05
47	24	22	038	2	09
48	20	10	064	2	12
49	16	8.5108297	089	3	16
50	8.5091611	8.5108285	1.34114	2.3823	6.1219
51	07	72	140	3	23
52	03	60	165	4	26
53	8.5091599	47	190	4	30
54	95	34	216	4	33
55	91	22	241	5	37
56	86	09	267	5	40
57	82	8.5108197	292	6	44
58	78	84	317	6	47
59	74	72	343	6	51
60	8.5091570	8.5108159	1 34368	2.3827	6.1255

LATITUDE 41°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.21	log **C** diff. 1″=+0.42	log **D** diff. 1″=+0.01	log **E** diff. 1″=+0.06
° ′					
41 00	8.5091570	8.5108159	1.34368	2.3827	6.1255
1	65	46	393	7	58
2	61	34	419	7	62
3	57	21	444	8	65
4	53	09	469	8	69
5	49	8.5108096	495	8	72
6	44	84	520	9	76
7	40	71	545	9	79
8	36	59	571	2.3830	83
9	32	46	596	0	86
10	8.5091528	8.5108033	1.34621	2.3830	6.1290
11	24	21	647	1	93
12	19	08	672	1	97
13	15	8.5107996	697	1	6.1301
14	11	83	723	2	04
15	07	71	748	2	08
16	03	58	773	2	11
17	8.5091498	45	799	3	15
18	94	33	824	3	18
19	90	20	850	3	22
20	8.5091486	8.5107908	1.34875	2.3834	6.1325
21	82	8.5107895	900	4	29
22	77	83	925	4	32
23	73	70	950	5	36
24	69	57	976	5	40
25	65	45	1.35001	5	43
26	61	32	026	6	47
27	56	20	052	6	50
28	52	07	077	6	54
29	48	8.5107794	102	7	57
30	8.5091444	8.5107782	1.35127	2.3837	6 1361
31	40	69	153	7	65
32	35	57	178	8	68
33	31	44	203	8	72
34	27	31	229	8	75
35	23	19	254	9	79
36	19	06	279	9	82
37	14	8.5107694	304	9	86
38	10	81	330	2.3840	89
39	06	68	355	0	93
40	8.5091402	8.5107656	1.35380	2.3840	6.1397
41	8.5091398	43	406	0	6.1400
42	93	31	431	1	04
43	89	18	456	1	07
44	85	05	481	1	11
45	81	8.5107593	507	2	14
46	77	80	532	2	18
47	72	68	557	2	22
48	68	55	582	3	25
49	64	42	608	3	29
50	8.5091360	8.5107530	1.35633	2.3843	6.1432
51	56	17	658	3	36
52	51	05	683	4	40
53	47	8.5107492	709	4	43
54	43	79	734	4	47
55	39	67	759	5	50
56	35	54	784	5	54
57	30	42	810	5	58
58	26	29	835	5	61
59	22	16	860	6	65
60	8.5091318	8.5107404	1.35885	2.3846	6.1468

LATITUDE 42°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.21	log **C** diff. 1″=+0.42	log **D** diff. 1″=+0.00	log **E** diff. 1″=+0.06
° ′					
42 00	8.5091318	8.5107404	1.35885	2.3846	6.1468
1	14	8.5107391	911	6	72
2	09	78	936	7	75
3	05	66	961	7	79
4	01	53	986	7	83
5	8.5091297	41	1.36012	7	86
6	93	28	037	8	90
7	88	15	062	8	93
8	84	03	087	8	97
9	80	8.5107290	113	8	6.1500
10	8.5091276	8.5107277	1.36138	2.3849	6.1504
11	72	65	163	9	08
12	67	52	188	9	11
13	63	40	213	2.3850	15
14	59	27	239	0	19
15	55	14	264	0	22
16	50	02	289	0	26
17	46	8.5107189	314	1	29
18	42	76	339	1	33
19	38	64	365	1	37
20	8.5091234	8.5107151	1.36390	2.3851	6.1540
21	29	39	415	2	44
22	25	26	440	2	48
23	21	13	466	2	51
24	17	01	491	2	55
25	13	8.5107088	516	3	58
26	08	75	541	3	62
27	04	63	566	3	66
28	00	50	591	3	69
29	8.5091196	38	617	3	73
30	8.5091192	8.5107025	1.36642	2.3854	6.1576
31	87	12	667	4	80
32	83	8.5107000	692	4	84
33	79	8.5106987	717	4	87
34	75	74	743	5	91
35	70	62	768	5	95
36	66	49	793	5	98
37	62	36	818	5	6.1602
38	58	24	843	6	05
39	54	11	869	6	09
40	8.5091149	8.5106898	1.36894	2.3856	6.1613
41	45	86	919	6	16
42	41	73	944	6	20
43	37	61	969	7	24
44	33	48	994	7	27
45	28	35	1.37020	7	31
46	24	23	045	7	35
47	20	10	070	7	38
48	16	8.5106797	095	8	42
49	11	85	120	8	46
50	8.5091107	8.5106772	1.37146	2.3858	6.1649
51	03	59	171	8	53
52	8.5091099	47	196	8	56
53	95	34	221	9	60
54	90	21	246	9	64
55	86	09	271	9	67
56	82	8.5106696	297	9	71
57	78	83	322	9	75
58	73	71	347	2.3860	78
59	69	58	372	0	82
60	8.5091065	8.5106645	1.37397	2.3860	6.1686

LATITUDE 43°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.21	log **C** diff. 1″=+0.42	log **D** diff. 1″=+0.00	log **E** diff. 1″=+0.06
° ′					
43 00	8.5091065	8.5106645	1.37397	2.3860	6.1686
1	61	33	422	0	89
2	57	20	447	0	93
3	52	07	473	1	97
4	48	8.5106595	498	1	6.1700
5	44	82	523	1	04
6	40	69	548	1	08
7	36	57	573	1	11
8	31	44	598	2	15
9	27	32	624	2	19
10	8.5091023	8.5106519	1.37649	2.3862	6.1722
11	19	06	674	2	26
12	14	8.5106494	699	2	30
13	10	81	724	2	33
14	06	68	749	3	37
15	02	56	774	3	41
16	8.5090998	43	800	3	44
17	93	30	825	3	48
18	89	18	850	3	52
19	85	05	875	3	55
20	8.5090981	8.5106392	1.37900	2.3864	6.1759
21	76	80	925	4	63
22	72	67	950	4	66
23	68	54	976	4	70
24	64	42	1.38001	4	74
25	60	29	026	4	77
26	55	16	051	4	81
27	51	04	076	5	85
28	47	8.5106291	101	5	88
29	43	78	126	5	92
30	8.5090938	8.5106266	1.38152	2.3865	6.1796
31	34	53	177	5	99
32	30	40	202	5	6.1803
33	26	28	227	5	07
34	22	15	252	6	10
35	17	02	277	6	14
36	13	8.5106189	302	6	18
37	09	77	327	6	22
38	05	64	353	6	25
39	00	51	378	6	29
40	8.5090896	8.5106139	1.38403	2.3866	6.1833
41	92	26	428	7	36
42	88	13	453	7	40
43	83	01	478	7	44
44	79	8.5106088	503	7	47
45	75	75	528	7	51
46	71	63	554	7	55
47	67	50	579	7	58
48	62	37	604	7	62
49	58	25	629	8	66
50	8.5090854	8.5106012	1.38654	2.3868	6.1870
51	50	8.5105999	679	8	73
52	45	87	704	8	77
53	41	74	729	8	81
54	37	61	754	8	84
55	33	49	780	8	88
56	29	36	805	8	92
57	24	23	830	8	96
58	20	11	855	9	99
59	16	8.5105898	880	9	6.1903
60	8.5090812	8.5105885	1.38905	2.3869	6.1907

LATITUDE 44°

Lat.	log A diff. 1″=−0.07	log B diff. 1″=−0.21	log C diff. 1″=+0.42	log D diff. 1″=+0.00	log E diff. 1″=+0.06
° ′					
44 00	8.5090812	8.5105885	1.38905	2.3869	6.1907
1	07	73	930	9	10
2	03	60	955	9	14
3	8.5090799	47	980	9	18
4	95	35	1.39006	9	22
5	90	22	031	9	25
6	86	09	056	9	29
7	82	8.5105796	081	9	33
8	78	84	106	2.3870	36
9	74	71	131	0	40
10	8.5090769	8.5105758	1.39156	2.3870	6.1944
11	65	46	181	0	48
12	61	33	206	0	51
13	57	20	232	0	55
14	52	08	257	0	59
15	48	8.5105695	282	0	63
16	44	82	307	0	66
17	40	70	332	0	70
18	36	57	357	0	74
19	31	44	382	0	78
20	8.5090727	8.5105632	1.39407	2.3871	6.1981
21	23	19	432	1	85
22	19	06	458	1	89
23	14	8.5105594	483	1	92
24	10	81	508	1	96
25	06	68	533	1	6.2000
26	02	55	558	1	04
27	8.5090698	43	583	1	07
28	93	30	608	1	11
29	89	17	633	1	15
30	8.5090685	8.5105505	1.39658	2.3871	6.2019
31	81	8.5105492	683	1	22
32	76	79	709	1	26
33	72	67	734	1	30
34	68	54	759	1	34
35	64	41	784	1	37
36	59	29	809	1	41
37	55	16	834	1	45
38	51	03	859	2	49
39	47	8.5105391	884	2	52
40	8.5090643	8.5105378	1.39909	2.3872	6.2056
41	38	65	934	2	60
42	34	52	960	2	64
43	30	40	985	2	68
44	26	27	1.40010	2	71
45	21	14	035	2	75
46	17	02	060	2	79
47	13	8.5105289	085	2	83
48	09	76	110	2	86
49	04	64	135	2	90
50	8.5090600	8.5105251	1.40160	2.3872	6.2094
51	8.5090596	38	185	2	98
52	92	26	210	2	6.2101
53	88	13	236	2	05
54	83	00	261	2	09
55	79	8.5105187	286	2	13
56	75	75	311	2	17
57	71	62	336	2	20
58	66	49	361	2	24
59	62	37	386	2	28
60	8.5090558	8.5105124	1.40411	2.3872	6.2132

LATITUDE 45°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.21	log **C** diff. 1″=+0.42	log **D** diff. 1″=±0.00	log **E** diff. 1″=+0.06
° ′					
45 00	8.5090558	8.5105124	1.40411	2.3872	6.2132
1	54	11	436	2	35
2	49	8.5105099	461	2	39
3	45	86	486	2	43
4	41	73	512	2	47
5	37	61	537	2	51
6	33	48	562	2	54
7	28	35	587	2	58
8	24	23	612	2	62
9	20	10	637	2	66
10	8.5090516	8.5104997	1.40662	2.3872	6.2170
11	11	84	687	2	73
12	07	72	712	2	77
13	03	59	738	2	81
14	8.5090499	46	763	2	85
15	94	34	788	2	89
16	90	21	813	2	92
17	86	08	838	2	96
18	82	8.5104896	863	2	6.2200
19	78	83	888	2	04
20	8.5090473	8.5104870	1.40913	2.3872	6.2208
21	69	58	938	2	11
22	65	45	963	2	15
23	61	32	989	2	19
24	56	19	1.41014	2	23
25	52	07	039	2	27
26	48	8.5104794	064	2	30
27	44	81	089	2	34
28	39	69	114	2	38
29	35	56	139	2	42
30	8.5090431	8.5104743	1.41164	2.3872	6.2246
31	27	31	189	2	49
32	23	18	214	2	53
33	18	05	240	2	57
34	14	8.5104693	265	2	61
35	10	80	290	2	65
36	06	67	315	2	69
37	01	55	340	2	72
38	8.5090397	42	365	2	76
39	93	29	390	2	80
40	8.5090389	8.5104616	1.41415	2.3872	6.2284
41	85	04	440	1	88
42	80	8.5104591	465	1	91
43	76	79	491	1	95
44	72	66	516	1	99
45	68	53	541	1	6.2303
46	63	40	566	1	6.2307
47	59	28	591	1	11
48	55	15	616	1	14
49	51	02	641	1	18
50	8.5090346	8.5104490	1.41666	2.3871	6.2322
51	42	77	691	1	26
52	38	64	717	1	30
53	34	52	742	1	34
54	30	39	767	1	37
55	25	26	792	1	41
56	21	14	817	1	45
57	17	01	842	1	49
58	13	8.5104388	867	0	53
59	08	75	892	0	57
60	8.5090304	8.5104363	1.41917	2.3870	6.2361

LATITUDE 46°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.21	log **C** diff. 1″=+0.42	log **D** diff. 1″=−0.00	log **E** diff. 1″=+0.06
° ′					
46 00	8.5090304	8.5104363	1.41917	2.3870	6.2361
1	00	50	943	0	64
2	8.5090296	37	968	0	68
3	91	25	993	0	72
4	87	12	1.42018	0	76
5	83	8.5104299	1.42043	0	80
6	79	87	068	0	84
7	75	74	093	0	88
8	70	61	118	0	91
9	66	49	143	0	95
10	8.5090262	8.5104236	1.42169	2 3869	6.2399
11	58	23	194	9	6.2403
12	53	11	219	9	07
13	49	8.5104198	244	9	11
14	45	85	269	9	15
15	41	73	294	9	18
16	37	60	319	9	22
17	32	47	344	9	26
18	28	35	370	9	30
19	24	22	395	9	34
20	8.5090220	8.5104109	1.42420	2.3868	6.2438
21	15	8.5104096	445	8	42
22	11	84	470	8	46
23	07	71	495	8	49
24	03	58	520	8	53
25	8.5090198	46	545	8	57
26	94	33	571	8	61
27	90	20	596	8	65
28	86	08	621	8	69
29	82	8.5103995	646	8	73
30	8.5090177	8.5103982	1.42671	2.3867	6.2477
31	73	70	696	7	80
32	69	57	721	7	84
33	65	44	746	7	88
34	60	32	772	7	92
35	56	19	797	7	96
36	52	06	822	7	6.2500
37	48	8.5103894	847	6	04
38	44	81	872	6	08
39	39	68	897	6	12
40	8.5090135	8.5103856	1.42922	2.3866	6.2515
41	31	43	948	6	19
42	27	30	973	6	23
43	22	18	998	6	27
44	18	05	1.43023	6	31
45	14	8.5103792	048	5	35
46	10	80	073	5	39
47	06	67	098	5	43
48	01	54	124	5	47
49	8.5090097	42	149	5	51
50	8.5090093	8.5103729	1.43174	2.3865	6.2554
51	89	16	199	5	58
52	84	04	224	4	62
53	80	8.5103691	249	4	66
54	76	78	274	4	70
55	72	66	300	4	74
56	68	53	325	4	78
57	63	40	350	4	82
58	59	28	375	3	86
59	55	15	400	3	90
60	8.5090051	8.5103602	1.43425	2.3863	6.2594

LATITUDE 47°

Lat.	log A diff. 1″=−0.07	log B diff. 1″=−0.21	log C diff. 1″=+0.42	log D diff. 1″=−0.00	log E diff. 1″=+0.07
° ′					
47 00	8.5090051	8.5103602	1.43425	2.3863	6.2594
1	46	8.5103590	451	3	97
2	42	77	476	3	6.2601
3	38	64	501	3	05
4	34	52	526	2	09
5	30	39	551	2	13
6	25	26	576	2	17
7	21	14	602	2	21
8	17	01	627	2	25
9	13	8.5103488	652	2	29
10	8.5090008	8.5103476	1.43677	2.3861	6.2633
11	04	63	702	1	37
12	00	50	727	1	41
13	8.5089996	38	753	1	45
14	92	25	778	1	49
15	87	12	803	0	53
16	83	00	828	0	56
17	79	8.5103387	853	0	60
18	75	74	878	0	64
19	71	62	904	0	68
20	8.5089966	8.5103349	1.43929	2.3860	6.2672
21	62	37	954	2.3859	76
22	58	24	979	9	80
23	54	11	1.44004	9	84
24	49	8.5103299	030	9	88
25	45	86	055	9	92
26	41	73	080	8	96
27	37	61	105	8	6.2700
28	33	48	130	8	04
29	28	35	155	8	08
30	8.5089924	8.5103223	1.44181	2.3858	6.2712
31	20	10	206	7	16
32	16	8.5103197	231	7	20
33	11	85	256	7	24
34	07	72	281	7	28
35	03	59	307	6	31
36	8.5089899	47	332	6	35
37	95	34	357	6	39
38	90	22	382	6	43
39	86	09	407	6	47
40	8.5089882	8.5103096	1.44433	2.3855	6.2751
41	78	84	458	5	55
42	74	71	483	5	59
43	69	58	508	5	63
44	65	46	534	4	67
45	61	33	559	4	71
46	57	20	584	4	75
47	53	08	609	4	79
48	48	8.5102995	634	4	83
49	44	83	660	3	87
50	8.5089840	8.5102970	1.44685	2.3853	6.2791
51	36	57	710	3	95
52	31	45	735	3	99
53	27	32	761	2	6.2803
54	23	19	786	2	07
55	19	07	811	2	11
56	15	8.5102894	836	2	15
57	10	82	861	1	19
58	06	69	887	1	23
59	02	56	912	1	27
60	8.5089798	8.5102844	1.44937	2.3851	6.2831

LATITUDE 48°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.21	log **C** diff. 1″=+0.42	log **D** diff. 1″=−0.00	log **E** diff. 1″=+0.07
° ′					
48 00	8.5089798	8.5102844	1.44937	2.3851	6.2831
1	94	31	962	0	35
2	89	18	988	0	39
3	85	06	1.45013	0	43
4	81	8.5102793	038	0	47
5	77	81	063	2.3849	51
6	73	68	089	9	55
7	68	55	114	9	59
8	64	43	139	9	63
9	60	30	164	8	67
10	8.5089756	8.5102717	1.45190	2.3848	6.2871
11	52	05	215	8	75
12	47	8.5102692	240	7	79
13	43	80	265	7	83
14	39	67	291	7	87
15	35	54	316	7	91
16	30	42	341	6	95
17	26	29	366	6	99
18	22	17	392	6	6.2903
19	18	04	417	6	07
20	8.5089714	8.5102591	1.45442	2.3845	6.2911
21	09	79	467	5	15
22	05	66	493	5	19
23	01	53	518	4	23
24	8.5089697	41	543	4	27
25	93	28	569	4	31
26	88	16	594	4	35
27	84	03	619	3	39
28	80	8.5102490	644	3	43
29	76	78	670	3	47
30	8.5089672	8.5102465	1.45695	2.3842	6.2951
31	67	53	720	2	55
32	63	40	746	2	59
33	59	27	771	1	63
34	55	15	796	1	67
35	51	02	821	1	71
36	46	8.5102390	847	1	75
37	42	77	872	0	79
38	38	64	897	0	83
39	34	52	923	0	87
40	8.5089630	8.5102339	1.45948	2.3839	6.2992
41	25	27	973	9	96
42	21	14	999	9	6.3000
43	17	02	1.46024	8	04
44	13	8.5102289	049	8	08
45	09	76	075	8	12
46	04	64	100	7	16
47	00	51	125	7	20
48	8.5089596	39	150	7	24
49	92	26	176	6	28
50	8.5089588	8.5102213	1.46201	2.3836	6.3032
51	84	01	226	6	36
52	79	8.5102188	252	5	40
53	75	76	277	5	44
54	71	63	302	5	48
55	67	51	328	4	52
56	63	38	353	4	56
57	58	25	378	4	60
58	54	13	404	3	65
59	50	00	429	3	69
60	8.5089546	8.5102088	1.46454	2.3833	6.3073

LATITUDE 49°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.21	log **C** diff. 1″=+0.42	log **D** diff. 1″=−0.00	log **E** diff. 1″=+0.07
° ′					
49 00	8.5089546	8.5102088	1.46454	2.3833	6.3073
1	42	75	480	2	77
2	37	62	505	2	81
3	33	50	531	2	85
4	29	37	556	1	89
5	25	25	581	1	93
6	21	12	607	1	97
7	16	00	632	0	6.3101
8	12	8.5101987	657	0	05
9	08	75	683	0	09
10	8.5089504	8.5101962	1.46708	2.3829	6.3113
11	00	49	733	9	17
12	8.5089496	37	759	9	22
13	91	24	784	8	26
14	87	12	810	8	30
15	83	8.5101899	835	8	34
16	79	87	860	7	38
17	75	74	886	7	42
18	70	61	911	6	46
19	66	49	936	6	50
20	8.5089462	8.5101836	1.46962	2.3826	6.3154
21	58	24	987	5	58
22	54	11	1.47013	5	62
23	49	8.5101799	038	4	67
24	45	86	063	4	71
25	41	74	089	4	75
26	37	61	114	3	79
27	33	49	140	3	83
28	29	36	165	3	87
29	24	23	190	2	91
30	8.5089420	8.5101711	1.47216	2.3822	6.3195
31	16	8.5101698	241	2	99
32	12	86	267	1	6.3203
33	08	73	292	1	08
34	03	61	318	0	12
35	8.5089399	48	343	0	16
36	95	36	368	0	20
37	91	23	394	2.3819	24
38	87	11	419	9	28
39	83	8.5101598	445	8	32
40	8.5089378	8.5101586	1.47470	2.3818	6.3236
41	74	73	496	7	41
42	70	61	521	7	45
43	66	48	546	7	49
44	62	35	572	6	53
45	58	23	597	6	57
46	53	10	623	5	61
47	49	8.5101498	648	5	65
48	45	85	674	5	69
49	41	73	699	4	74
50	8.5089337	8.5101460	1.47725	2.3814	6.3278
51	33	48	750	3	82
52	28	35	776	3	86
53	24	23	801	2	90
54	20	10	827	2	94
55	16	8.5101398	852	2	98
56	12	85	877	1	6.3303
57	07	73	903	1	07
58	03	60	928	0	11
59	8.5089299	48	954	0	15
60	8.5089295	8.5101335	1.47979	2.3809	6.3319

LATITUDE 50°

Lat.	log A diff. 1″=−0.07	log B diff. 1″=−0.21	log C diff. 1″=+0.43	log D diff. 1″=−0.01	log E diff. 1″=+0.07
° ′					
50 00	8.5089295	8.5101335	1.47979	2.3809	6.3319
1	91	23	1.48005	9	23
2	87	10	030	9	27
3	82	8.5101298	056	8	32
4	78	85	081	8	36
5	74	73	107	7	40
6	70	60	132	7	44
7	66	48	158	6	48
8	61	35	183	6	52
9	57	23	209	5	56
10	8.5089253	8.5101210	1.48234	2.3805	6.3361
11	49	8.5101198	260	5	65
12	45	85	286	4	69
13	40	73	311	4	73
14	36	60	337	3	77
15	32	48	362	3	81
16	28	35	388	2	86
17	24	23	413	2	90
18	19	10	439	1	94
19	15	8.5101098	464	1	98
20	8.5089211	8.5101085	1.48490	2.3801	6.3402
21	07	73	515	0	07
22	03	60	541	0	11
23	8.5089199	48	566	2.3799	15
24	95	35	592	9	19
25	90	23	618	8	23
26	86	11	643	8	27
27	82	8.5100998	669	7	32
28	78	85	694	7	36
29	74	73	720	6	40
30	8.5089170	8.5100960	1.48745	2.3796	6.3444
31	65	48	771	5	48
32	61	35	797	5	53
33	57	23	822	4	57
34	53	10	848	4	61
35	49	8.5100898	873	3	65
36	45	85	899	3	69
37	40	73	924	2	73
38	36	60	950	2	78
39	32	48	976	1	82
40	8.5089128	8.5100835	1.49001	2.3791	6.3486
41	24	23	027	0	90
42	20	10	052	0	94
43	15	8.5100798	078	2.3789	99
44	11	85	104	9	6.3503
45	07	73	129	8	07
46	03	61	155	8	11
47	8.5089099	48	180	7	16
48	95	36	206	7	20
49	90	23	232	6	24
50	8.5089086	8.5100711	1.49257	2.3786	6.3528
51	82	8.5100699	283	5	32
52	78	86	309	5	37
53	74	74	334	4	41
54	70	61	360	4	45
55	66	49	386	3	49
56	62	37	411	3	54
57	58	24	437	2	58
58	53	12	463	2	62
59	49	8.5100599	488	1	66
60	8.5089045	8.5100587	1.49514	2.3781	6.3570

LATITUDE 51°

Lat.	log A diff. 1″=−0.07	log B diff. 1″=−0.21	log C diff. 1″=+0.43	log D diff. 1″=−0.01	log E diff. 1″=+0.07
° ′					
51 00	8.5089045	8.5100587	1.49514	2.3781	6.3570
1	41	75	540	0	75
2	37	62	565	0	79
3	32	50	591	2.3779	83
4	28	37	617	9	87
5	24	25	642	8	92
6	20	13	668	8	96
7	16	00	694	7	6.3600
8	12	8.5100488	719	7	04
9	08	75	745	6	09
10	8.5089003	8.5100463	1.49771	2.3775	6.3613
11	8.5088999	51	796	5	17
12	95	38	822	4	21
13	91	26	848	4	26
14	87	13	873	3	30
15	83	01	899	3	34
16	79	8.5100389	925	2	38
17	75	76	951	2	43
18	70	64	976	1	47
19	66	51	1.50002	0	51
20	8.5088962	8.5100339	1.50028	2.3770	6.3655
21	58	27	053	2.3769	60
22	54	14	079	9	64
23	50	02	105	8	68
24	46	8.5100289	131	8	72
25	42	77	156	7	77
26	38	65	182	7	81
27	34	52	208	6	85
28	29	40	234	5	89
29	25	27	259	5	94
30	8.5088921	8.5100215	1.50285	2.3764	6.3698
31	17	03	311	4	6.3702
32	13	8.5100190	337	3	07
33	09	78	363	3	11
34	05	66	388	2	15
35	01	53	414	1	19
36	8.5088897	41	440	1	24
37	93	29	466	0	28
38	88	16	491	0	32
39	84	04	517	2.3759	37
40	8.5088880	8.5100091	1.50543	2.3759	6.3741
41	76	79	569	8	45
42	72	67	595	7	49
43	68	54	621	7	54
44	63	42	646	6	58
45	59	29	672	6	62
46	55	16	698	5	67
47	51	04	724	4	71
48	47	8.5099991	750	4	75
49	43	79	775	3	79
50	8.5088838	8.5099967	1.50801	2.3753	6.3784
51	34	55	827	2	88
52	30	42	853	1	92
53	26	30	879	1	97
54	22	17	905	0	6.3801
55	18	05	931	0	05
56	14	8.5099893	956	2.3749	10
57	10	81	982	8	14
58	05	69	1.51008	8	18
59	01	56	034	7	23
60	8.5088797	8.5099844	1.51060	2.3747	6.3827

LATITUDE 52°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.20	log **C** diff. 1″=+0.43	log **D** diff. 1″=−0.01	log **E** diff. 1″=+0.07
° ′					
52 00	8.5088797	8.5099844	1.51060	2.3747	6.3827
1	93	32	086	6	31
2	89	19	112	5	36
3	85	07	138	5	40
4	81	8.5099795	163	4	44
5	77	82	189	3	48
6	73	70	215	3	53
7	69	58	241	2	57
8	65	46	267	2	61
9	61	33	293	1	66
10	8.5088756	8.5099721	1.51319	2.3740	6.3870
11	52	09	345	0	74
12	48	8.5099696	371	2.3739	79
13	44	84	397	8	83
14	40	72	423	8	88
15	36	60	448	7	92
16	32	47	474	6	96
17	28	35	500	6	6.3901
18	24	23	526	5	05
19	20	10	552	4	09
20	8.5088715	8.5099598	1.51578	2.3734	6.3914
21	11	86	604	3	18
22	07	73	630	3	22
23	03	61	656	2	27
24	8.5088699	49	682	1	31
25	95	37	708	1	35
26	91	25	734	0	40
27	87	12	760	2.3729	44
28	83	00	786	9	48
29	79	8.5099487	812	8	53
30	8.5088674	8.5099475	1.51838	2.3727	6.3957
31	70	63	864	7	62
32	66	50	890	6	66
33	62	38	916	5	70
34	58	26	942	5	75
35	54	14	968	4	79
36	50	02	994	3	83
37	46	8.5099389	1.52020	3	88
38	42	77	046	2	92
39	38	64	072	1	97
40	8.5088633	8.5099352	1.52098	2.3721	6.4001
41	29	40	124	0	05
42	25	28	150	2.3719	10
43	21	15	176	8	14
44	17	03	202	8	18
45	13	8.5099291	228	7	23
46	09	79	254	6	27
47	05	67	280	6	32
48	01	54	307	5	36
49	8.5088597	42	333	4	40
50	8.5088593	8.5099230	1.52359	2.3714	6 4045
51	89	18	385	3	49
52	85	06	411	2	54
53	81	8.5099193	437	2	58
54	77	81	463	1	62
55	72	69	489	0	67
56	68	57	515	2.3709	71
57	64	45	541	9	76
58	60	32	567	8	80
59	56	20	593	7	84
60	8.5088552	8.5099108	1.52620	2.3707	6.4089

LATITUDE 53°

Lat.	log A diff. 1″ = −0.07	log B diff. 1″ = −0.20	log C diff. 1″ = +0.44	log D diff. 1″ = −0.01	log E diff. 1″ = +0.08
° ′					
53 00	8.5088552	8.5099108	1.52620	2.3707	6.4089
1	48	8.5099096	646	6	93
2	44	84	672	5	98
3	40	71	698	4	6.4102
4	36	59	724	4	07
5	32	47	750	3	11
6	28	35	776	2	15
7	24	23	803	2	20
8	19	10	829	1	24
9	15	8.5098998	855	0	29
10	8.5088511	8.5098986	1.52881	2.3699	6.4133
11	07	73	907	9	37
12	03	61	933	8	42
13	8.5088499	49	960	7	46
14	95	37	986	6	51
15	91	25	1.53012	6	55
16	87	13	038	5	60
17	83	01	064	4	64
18	79	8.5098889	091	4	68
19	75	77	117	3	73
20	8.5088470	8.5098864	1.53143	2.3692	6.4177
21	66	52	169	1	82
22	62	40	195	1	86
23	58	28	222	0	91
24	54	16	248	2.3689	95
25	50	04	274	8	6.4200
26	46	8.5098791	300	8	04
27	42	79	327	7	08
28	38	67	353	6	13
29	34	55	379	5	17
30	8.5088430	8.5098743	1.53405	2.3685	6.4222
31	26	30	432	4	26
32	22	18	458	3	31
33	18	06	484	2	35
34	14	8.5098694	510	1	40
35	10	82	537	1	44
36	06	70	563	0	49
37	02	58	589	2.3679	53
38	8.5088398	46	616	8	58
39	94	34	642	8	62
40	8.5088390	8.5098621	1.53668	2.3677	6.4267
41	86	09	694	6	71
42	82	8.5098597	721	5	76
43	78	85	747	5	80
44	74	73	773	4	85
45	70	61	800	3	89
46	66	49	826	2	93
47	61	37	852	1	98
48	57	25	879	1	6.4302
49	53	13	905	0	07
50	8.5088349	8.5098500	1.53931	2.3669	6.4311
51	45	8.5098488	958	8	16
52	41	76	984	7	20
53	37	64	1.54011	7	25
54	33	52	037	6	29
55	29	40	063	5	34
56	25	28	090	4	38
57	21	16	116	3	43
58	17	04	142	3	47
59	13	8.5098392	169	2	52
60	8.5088309	8.5098379	1.54195	2.3661	6.4356

LATITUDE 54°

Lat.	log A	log B	log C	log D	log E
	diff. 1″=−0.07	diff. 1″=−0.20	diff. 1″=+0.44	diff. 1″=−0.01	diff. 1″=+0.08
° ′					
54 00	8.5088309	8.5098379	1.54195	2.3661	6.4356
1	05	67	222	0	61
2	01	55	248	2.3659	65
3	8.5088297	43	275	9	70
4	93	31	301	8	75
5	89	19	327	7	79
6	85	07	354	6	84
7	81	8.5098295	380	5	88
8	77	83	407	4	93
9	73	71	433	4	97
10	8.5088269	8.5098258	1.54460	2 3653	6.4402
11	65	46	486	2	06
12	61	34	513	1	11
13	57	22	539	0	15
14	53	10	565	2.3649	20
15	49	8.5098198	592	9	24
16	45	86	618	8	29
17	41	74	645	7	33
18	37	62	671	6	38
19	33	50	698	5	43
20	8.5088229	8.5098138	1.54724	2.3644	6.4447
21	25	26	751	4	52
22	21	14	777	3	56
23	17	02	804	2	61
24	13	8.5098090	831	1	65
25	09	78	857	0	70
26	05	66	884	2.3639	74
27	01	53	910	8	79
28	8.5088197	41	937	8	83
29	93	29	963	7	88
30	8.5088189	8.5098017	1.54990	2.3636	6.4493
31	85	05	1.55016	5	97
32	81	8.5097993	043	4	6.4502
33	77	81	070	3	06
34	73	69	096	3	11
35	69	57	123	2	15
36	65	45	149	1	20
37	61	33	176	0	25
38	57	21	202	2.3629	29
39	53	09	229	8	34
40	8.5088149	8.5097897	1.55256	2.3627	6.4538
41	45	85	282	6	43
42	41	73	309	6	47
43	37	61	336	5	52
44	33	49	362	4	57
45	29	37	389	3	61
46	26	25	415	2	66
47	22	13	442	1	70
48	18	01	469	0	75
49	14	8.5097789	495	2.3619	80
50	8.5088110	8.5097777	1.55522	2.3619	6.4584
51	06	65	549	8	89
52	02	53	575	7	93
53	8.5088098	41	602	6	98
54	94	29	629	5	6.4603
55	90	18	656	4	07
56	86	06	682	3	12
57	82	8.5097694	709	2	16
58	78	82	736	1	21
59	74	70	762	0	26
60	8.5088070	8.5097658	1.55789	2.3610	6.4630

LATITUDE 55°

Lat.	log **A** diff. 1″ = −0.07	log **B** diff. 1″ = −0.20	log **C** diff. 1″ = +0.45	log **D** diff. 1″ = −0.02	log **E** diff. 1″ = +0.08
° ′					
55 00	8.5088070	8.5097658	1.55789	2.3610	6.4630
1	66	46	816	2.3609	35
2	62	34	843	8	39
3	58	22	869	7	44
4	54	11	896	6	49
5	50	8.5097599	923	5	53
6	46	87	950	4	58
7	42	75	976	3	62
8	38	63	1.56003	2	67
9	34	51	030	1	72
10	8.5088030	8.5097539	1.56057	2.3600	6.4676
11	26	27	083	2.3599	81
12	22	15	110	8	86
13	18	04	137	8	90
14	14	8.5097492	164	7	95
15	10	80	191	6	6.4700
16	06	68	218	5	04
17	02	56	244	4	09
18	8.5087998	44	271	3	13
19	94	32	298	2	18
20	8.5087990	8.5097420	1.56325	2.3591	6.4723
21	86	08	352	0	27
22	82	8.5097396	379	2.3589	32
23	78	85	405	8	37
24	74	73	432	7	41
25	70	61	459	6	46
26	67	49	486	5	51
27	63	37	513	4	55
28	59	25	540	3	60
29	55	13	567	3	65
30	8.5087951	8.5097301	1.56594	2.3582	6.4769
31	47	8.5097290	620	1	74
32	43	78	647	0	79
33	39	66	674	2.3579	83
34	35	54	701	8	88
35	31	42	728	7	93
36	28	30	755	6	97
37	24	18	782	5	6.4802
38	20	06	809	4	07
39	16	8.5097194	836	3	11
40	8.5087912	8.5097182	1.56863	2.3572	6.4816
41	08	71	890	1	21
42	04	59	917	0	26
43	00	47	944	2.3569	30
44	8.5087896	35	971	8	35
45	92	23	998	7	40
46	88	11	1.57025	6	44
47	84	8.5097099	052	5	49
48	80	87	079	4	54
49	76	75	106	3	58
50	8.5087872	8.5097064	1.57133	2.3562	6.4863
51	68	52	160	1	68
52	64	41	187	0	73
53	60	29	214	2.3559	77
54	56	17	241	8	82
55	52	05	268	7	87
56	49	8.5096993	295	6	91
57	45	81	322	5	96
58	41	69	349	4	6.4901
59	37	58	376	3	06
60	8.5087833	8.5096946	1.57403	2.3552	6.4910

LATITUDE 56°

Lat.	log **A** diff. 1″=−0.07	log **B** diff. 1″=−0.19	log **C** diff. 1″=+0.45	log **D** diff. 1″=−0.02	log **E** diff. 1″=+0.08
° ′					
56 00	8.5087833	8.5096946	1.57403	2.3552	6.4910
1	29	34	431	1	15
2	25	22	458	0	20
3	21	11	485	2.3549	24
4	17	8.5096899	512	8	29
5	13	87	539	7	34
6	09	75	566	6	39
7	05	63	593	5	43
8	01	52	620	4	48
9	8.5087798	40	648	3	53
10	8.5087794	8.5096828	1.57675	2.3542	6.4958
11	90	16	702	1	62
12	86	05	729	0	67
13	82	8.5096793	756	2.3539	72
14	78	81	784	8	77
15	74	70	811	7	81
16	70	58	838	6	86
17	66	46	865	5	91
18	62	34	892	4	96
19	58	23	919	2	6.5000
20	8.5087754	8.5096711	1.57947	2.3531	6.5005
21	50	00	974	0	10
22	46	8.5096688	1.58001	2.3529	15
23	43	76	028	8	19
24	39	64	056	7	24
25	35	53	083	6	29
26	31	41	110	5	34
27	27	29	137	4	39
28	23	18	165	3	43
29	19	06	192	2	48
30	8.5087715	8.5096594	1.58219	2.3521	6.5053
31	11	83	247	0	58
32	07	71	274	2.3519	62
33	03	59	301	8	67
34	00	48	329	7	72
35	8.5087696	36	356	6	77
36	92	24	383	5	82
37	88	12	411	3	86
38	84	01	438	2	91
39	80	8.5096489	465	1	96
40	8.5087676	8.5096477	1.58493	2.3510	6.5101
41	73	66	520	2.3509	06
42	69	54	547	8	10
43	65	42	575	7	15
44	61	31	602	6	20
45	57	19	630	5	25
46	53	07	657	4	30
47	49	8.5096395	684	3	35
48	45	83	712	2	39
49	41	72	739	1	44
50	8.5087637	8.5096360	1.58766	2.3499	6.5149
51	34	49	794	8	54
52	30	37	821	7	59
53	26	26	849	6	63
54	22	14	876	5	68
55	18	02	904	4	73
56	14	8.5096291	931	3	78
57	10	79	959	2	83
58	06	67	986	1	88
59	02	56	1.59014	2.3489	92
60	8.5087598	8.5096244	1.59041	2.3488	6.5197

LATITUDE 57°

Lat.	log **A** diff. 1″=−0.06	log **B** diff. 1″=−0.19	log **C** diff. 1″=+0.46	log **D** diff. 1″=−0.02	log **E** diff. 1″=+0.08
° ′					
57 00	8.5087598	8.5096244	1.59041	2.3488	6.5197
1	95	33	069	7	6.5202
2	91	21	096	6	07
3	87	09	124	5	12
4	83	8.5096198	151	4	17
5	79	86	179	3	21
6	75	75	206	2	26
7	71	63	234	1	31
8	68	51	261	2.3479	36
9	64	40	289	8	41
10	8.5087560	8.5096128	1.59317	2.3477	6.5246
11	56	17	344	6	51
12	52	05	372	5	55
13	48	8.5096093	399	4	60
14	44	82	427	3	65
15	40	70	455	1	70
16	37	59	482	0	75
17	33	47	510	2.3469	80
18	29	35	537	8	85
19	25	24	565	7	90
20	8.5087521	8.5096012	1.59593	2.3466	6.5294
21	18	01	620	5	99
22	14	8.5095989	648	3	6.5304
23	10	77	676	2	09
24	06	66	703	1	14
25	02	54	731	0	19
26	8.5087498	43	759	2.3459	24
27	95	31	786	8	29
28	91	20	814	6	34
29	87	08	842	5	39
30	8.5087483	8.5095897	1.59870	2.3454	6.5343
31	79	85	897	3	48
32	75	74	925	2	53
33	71	62	953	1	58
34	67	51	981	2.3449	63
35	63	39	1.60008	8	68
36	60	28	036	7	73
37	56	17	064	6	78
38	52	05	092	5	83
39	48	8.5095794	119	4	88
40	8.5087444	8.5095782	1.60147	2.3442	6.5393
41	41	71	175	1	97
42	37	59	203	0	6.5402
43	33	48	231	2.3439	07
44	29	36	259	8	12
45	25	25	286	6	17
46	21	13	314	5	22
47	18	02	342	4	27
48	14	8.5095690	370	3	32
49	10	79	398	2	37
50	8.5087406	8.5095667	1.60426	2.3430	6.5442
51	02	56	453	2.3429	47
52	8.5087398	44	481	8	52
53	95	33	509	7	57
54	91	21	537	6	62
55	87	10	565	4	67
56	83	8.5095599	593	3	72
57	79	87	621	2	77
58	75	76	649	1	82
59	72	64	677	0	87
60	8.5087368	8.5095553	1.60705	2.3418	6.5491

LATITUDE 58°

Lat.	log A diff. 1″=−0.06	log B diff. 1″=−0.19	log C diff. 1″=+0.47	log D diff. 1″=−0.02	log E diff. 1″=+0.08
° ′					
58 00	8.5087368	8.5095553	1.60705	2.3418	6.5491
1	64	42	733	7	96
2	60	30	761	6	6.5501
3	57	19	789	5	06
4	53	07	817	3	11
5	49	8.5095496	845	2	16
6	45	85	873	1	21
7	41	73	901	0	26
8	38	62	929	2.3409	31
9	34	50	957	7	36
10	8.5087330	8.5095439	1.60985	2.3406	6.5541
11	26	28	1.61013	5	46
12	22	16	041	4	51
13	19	05	069	2	56
14	15	8.5095393	097	1	61
15	11	82	125	0	66
16	07	71	153	2.3399	71
17	03	59	181	7	76
18	00	48	209	6	81
19	8.5087296	36	237	5	86
20	8.5087292	8.5095325	1.61265	2.3394	6.5591
21	88	14	294	2	96
22	84	02	322	1	6.5601
23	81	8.5095291	350	0	06
24	77	80	378	2.3389	11
25	73	68	406	7	16
26	69	57	434	6	21
27	65	46	463	5	26
28	62	35	491	3	31
29	58	23	519	2	37
30	8.5087254	8.5095212	1.61547	2.3381	6.5642
31	50	01	575	0	47
32	47	8.5095189	604	2.3378	52
33	43	78	632	7	57
34	39	67	660	6	62
35	35	56	688	4	67
36	32	44	717	3	72
37	28	33	745	2	77
38	24	22	773	1	82
39	20	10	801	2.3369	87
40	8.5087217	8.5095099	1.61830	2.3368	6.5692
41	13	88	858	7	97
42	09	76	886	5	6.5702
43	06	65	915	4	07
44	02	54	943	3	12
45	8.5087198	43	971	2	17
46	94	31	1.62000	0	22
47	90	20	028	2.3359	27
48	87	09	056	8	32
49	83	8.5094997	085	6	37
50	8.5087179	8.5094986	1.62113	2.3355	6.5743
51	75	75	141	4	48
52	72	64	170	2	53
53	68	52	198	1	58
54	64	41	227	0	63
55	60	30	255	2.3348	68
56	57	19	284	7	73
57	53	08	312	6	78
58	49	8.5094896	340	4	83
59	46	85	369	3	88
60	8.5087142	8.5094874	1.62397	2.3342	6.5793

LATITUDE 59°

Lat.	log A diff. 1″=−0.06	log B diff. 1″=−0.19	log C diff. 1″=+0.48	log D diff. 1″=−0.02	log E diff. 1″=+0.09
° ′					
59 00	8.5087142	8.5094874	1.62397	2.3342	6.5793
1	38	63	426	0	99
2	35	52	454	2.3339	6.5804
3	31	40	483	8	09
4	27	29	511	6	14
5	23	18	540	5	19
6	20	07	568	4	24
7	16	8.5094796	597	2	29
8	12	84	625	1	34
9	09	73	654	0	40
10	8.5087105	8.5094762	1.62682	2.3328	6.5845
11	01	51	711	7	50
12	8.5087097	40	740	6	55
13	94	28	768	4	60
14	90	17	797	3	65
15	86	06	825	2	70
16	82	8.5094695	854	0	75
17	78	84	883	2.3319	81
18	75	72	911	7	86
19	71	61	940	6	91
20	8.5087067	8.5094650	1.62968	2.3315	6.5896
21	63	39	997	3	6.5901
22	60	28	1.63026	2	06
23	56	17	054	1	11
24	52	06	083	2.3309	17
25	48	8.5094594	112	8	22
26	45	83	140	6	27
27	41	72	169	5	32
28	37	61	198	4	37
29	34	50	227	2	42
30	8.5087030	8.5094539	1.63255	2.3301	6.5948
31	26	28	284	0	53
32	23	17	313	2.3298	58
33	19	06	342	7	63
34	15	8.5094495	370	5	68
35	11	84	399	4	74
36	08	72	428	3	79
37	04	61	457	1	84
38	00	50	486	0	89
39	8.5086997	39	514	2.3288	94
40	8.5086993	8.5094428	1.63543	2.3287	6.5999
41	89	17	572	6	6.6005
42	86	06	601	4	10
43	82	8.5094395	630	3	15
44	78	84	659	1	20
45	75	73	688	0	25
46	71	61	716	2.3278	31
47	67	50	745	7	36
48	63	39	774	6	41
49	60	28	803	4	46
50	8.5086956	8.5094317	1.63832	2.3273	6.6051
51	52	06	861	1	57
52	49	8.5094295	890	0	62
53	45	84	919	2.3268	67
54	41	73	948	7	72
55	38	62	977	6	78
56	34	51	1.64006	4	83
57	30	40	035	3	88
58	27	29	064	1	93
59	23	18	093	0	98
60	8.5086919	8.5094207	1.64122	2.3258	6.6104

LATITUDE 60°

Lat.	log **A** diff. 1″=−0.06	log **B** diff. 1″=−0.18	log **C** diff. 1″=+0.49	log **D** diff. 1″=−0.02	log **E** diff. 1″=+0.09
° ′					
60 00	8.5086919	8.5094207	1.64122	2.3258	6.6104
1	16	8.5094196	151	7	09
2	12	85	180	6	14
3	09	74	209	4	19
4	05	63	238	3	25
5	01	52	267	1	30
6	8.5086898	41	296	0	35
7	94	30	325	2.3248	41
8	90	19	354	7	46
9	87	08	383	5	51
10	8.5086883	8.5094097	1.64413	2.3244	6.6156
11	79	86	442	2	62
12	76	75	471	1	67
13	72	64	500	2.3239	72
14	68	53	529	8	77
15	64	42	558	6	83
16	61	31	588	5	88
17	57	20	617	3	93
18	53	09	646	2	99
19	50	8.5093998	675	1	6.6204
20	8.5086846	8.5093987	1.64704	2.3229	6.6209
21	43	76	734	8	14
22	40	65	763	6	20
23	36	54	792	5	25
24	32	43	821	3	30
25	28	33	851	2	36
26	25	22	880	0	41
27	21	11	909	2.3219	46
28	17	00	939	7	52
29	14	8.5093889	968	6	57
30	8.5086810	8.5093878	1.64997	2.3214	6.6262
31	06	67	1.65027	3	68
32	03	56	056	1	73
33	8.5086799	45	085	0	78
34	96	34	115	2.3208	84
35	92	24	144	6	89
36	88	13	173	5	94
37	85	02	203	3	6.6300
38	81	8.5093791	232	2	05
39	77	80	262	0	10
40	8.5086774	8.5093769	1.65291	2.3199	6.6316
41	70	58	320	7	21
42	67	47	350	6	26
43	63	37	379	4	32
44	60	26	409	3	37
45	56	15	438	1	42
46	52	04	468	0	48
47	49	8.5093693	497	2.3188	53
48	45	83	527	7	58
49	42	72	556	5	64
50	8.5086738	8.5093661	1.65586	2.3184	6.6369
51	34	50	615	2	75
52	31	39	645	0	80
53	27	29	675	2.3179	85
54	24	18	704	7	91
55	20	07	734	6	96
56	16	8.5093596	763	4	6.6401
57	13	85	793	3	07
58	09	75	823	1	12
59	06	64	852	0	18
60	8.5086702	8.5093553	1.65882	2.3168	6.6423

LATITUDE 61°

Lat.	log A diff. 1″ = −0.06	log B diff. 1″ = −0.18	log C diff. 1″ = +0.50	log D diff. 1″ = −0.03	log E diff. 1″ = +0.09
° ′					
61 00	8.5086702	8.5093553	1.65882	2.3168	6.6423
1	8.5086698	42	912	6	28
2	95	31	941	5	34
3	91	21	971	3	39
4	88	10	1.66000	2	45
5	84	8.5093499	030	0	50
6	80	88	060	2.3158	56
7	77	77	090	7	61
8	74	67	119	5	66
9	70	56	149	4	72
10	8.5086666	8.5093445	1.66179	2.3152	6.6477
11	62	34	209	1	83
12	59	24	238	2.3149	88
13	55	13	268	7	93
14	52	02	298	6	99
15	48	8.5093391	328	4	6.6504
16	44	81	358	3	10
17	41	70	387	1	15
18	37	59	417	2.3139	21
19	34	49	447	8	26
20	8.5086630	8.5093338	1.66477	2.3136	6.6531
21	26	27	507	5	37
22	23	17	537	3	42
23	19	06	567	1	48
24	16	8.5093295	597	0	53
25	12	85	626	2.3128	59
26	08	74	656	6	64
27	05	63	686	5	70
28	01	52	716	3	75
29	8.5086598	42	746	2	81
30	8.5086594	8.5093231	1.66776	2.3120	6.6586
31	90	20	806	2.3118	92
32	87	10	836	7	97
33	83	8.5093199	866	5	6.6603
34	80	89	896	3	08
35	77	78	926	2	14
36	73	67	956	0	19
37	69	57	986	2.3108	25
38	66	46	1.67017	7	30
39	62	36	047	5	36
40	8.5086559	8.5093125	1.67077	2.3104	6.6641
41	55	14	107	2	47
42	52	04	137	0	52
43	48	8.5093093	167	2.3099	58
44	45	83	197	7	63
45	42	72	227	5	69
46	38	61	258	4	74
47	34	51	288	2	80
48	30	40	318	0	85
49	27	30	348	2.3089	91
50	8.5086523	8.5093019	1.67378	2.3087	6.6696
51	20	08	409	5	6.6702
52	17	8.5092998	439	4	07
53	13	87	469	2	13
54	10	77	499	0	18
55	06	66	530	2.3079	24
56	03	55	560	7	30
57	8.5086499	45	590	5	35
58	96	34	620	4	41
59	92	24	651	2	46
60	8.5086488	8.5092913	1.67681	2.3070	6.6752

LATITUDE 62°

Lat.	log **A**	log **B**	log **C**	log **D**	log **E**
	diff. 1″=−0.06	diff. 1″=−0.17	diff. 1″=+0.51	diff. 1″=−0.03	diff. 1″=+0.09
° ′					
62 00	8.5086488	8.5092913	1.67681	2.3070	6.6752
1	85	03	711	2.3068	57
2	81	8.5092892	742	7	63
3	78	82	772	5	68
4	74	71	802	3	74
5	71	61	833	2	80
6	67	51	863	0	85
7	64	40	894	2.3058	91
8	60	29	924	7	96
9	56	18	955	5	6.6802
10	8.5086453	8.5092808	1.67985	2.3053	6.6808
11	49	8.5092798	1.68015	1	13
12	46	87	046	0	19
13	42	77	076	2.3048	24
14	39	66	107	6	30
15	36	56	137	4	36
16	32	45	168	3	41
17	29	34	199	1	47
18	25	24	229	2.3039	52
19	22	13	260	8	58
20	8.5086418	8.5092703	1.68290	2.3036	6.6864
21	15	8.5092693	321	4	69
22	11	82	351	2	75
23	08	72	382	1	80
24	04	61	413	2.3029	86
25	01	51	443	7	92
26	8.5086397	41	474	5	97
27	94	30	505	4	6.6903
28	90	20	535	2	09
29	87	09	566	0	14
30	8.5086383	8.5092599	1.68597	2.3018	6.6920
31	80	89	627	7	26
32	76	78	658	5	31
33	73	68	689	3	37
34	69	57	720	1	43
35	66	47	750	2.3009	48
36	63	37	781	8	54
37	59	26	812	6	60
38	56	16	843	4	65
39	52	05	873	2	71
40	8.5086349	8.5092495	1.68904	2.3001	6.6977
41	46	85	935	2.2999	82
42	42	74	966	7	88
43	39	64	997	5	94
44	35	53	1.69028	3	99
45	32	43	059	2	6.7005
46	29	33	090	0	11
47	25	22	120	2.2988	16
48	22	12	151	6	22
49	18	01	182	5	28
50	8.5086315	8.5092391	1.69213	2.2983	6.7034
51	12	81	244	1	39
52	08	70	275	2.2979	45
53	05	60	306	7	51
54	01	50	337	6	56
55	8.5086298	40	368	4	62
56	94	29	399	2	68
57	91	19	430	0	74
58	87	09	461	2.2968	79
59	83	8.5092298	492	6	85
60	8.5086280	8.5092288	1.69524	2.2965	6.7091

LATITUDE 63°

Lat.	log **A** diff. 1″ = −0.06	log **B** diff. 1″ = −0.17	log **C** diff. 1″ = +0.52	log **D** diff. 1″ = −0.03	log **E** diff. 1″ = +0.10
° ′					
63 00	8.5086280	8.5092288	1.69524	2.2965	6.7091
1	77	78	555	3	97
2	73	67	586	1	6.7102
3	70	57	617	2.2959	08
4	66	47	648	7	14
5	63	37	679	5	20
6	60	26	710	4	25
7	56	16	742	2	31
8	53	06	773	0	37
9	49	8.5092195	804	2.2948	43
10	8.5086246	8.5092185	1.69835	2.2946	6.7148
11	43	75	866	4	54
12	39	65	898	3	60
13	36	54	929	1	66
14	32	44	960	2.2939	72
15	29	34	991	7	77
16	26	24	1.70023	5	83
17	22	14	054	3	89
18	19	03	085	1	95
19	15	8.5092093	117	0	6.7201
20	8.5086212	8.5092083	1.70148	2.2928	6.7206
21	09	73	179	6	12
22	05	63	211	4	18
23	02	52	242	2	24
24	8.5086198	42	274	0	30
25	95	32	305	2.2918	35
26	92	22	337	6	41
27	88	12	368	4	47
28	85	01	399	3	53
29	81	8.5091991	431	1	59
30	8.5086178	8.5091981	1.70462	2.2909	6.7265
31	75	71	494	7	70
32	71	61	525	5	76
33	68	51	557	3	82
34	64	41	589	1	88
35	61	31	620	2.2899	94
36	58	20	652	7	6.7300
37	54	10	683	5	05
38	51	00	715	4	11
39	47	8.5091890	746	2	17
40	8.5086144	8.5091880	1.70778	2.2890	6.7323
41	41	70	810	2.2888	29
42	37	60	841	6	35
43	34	50	873	4	41
44	31	40	905	2	47
45	28	30	937	0	52
46	24	19	968	2.2878	58
47	21	09	1.71000	6	64
48	18	8.5091799	032	4	70
49	14	89	064	2	76
50	8.5086111	8.5091779	1.71095	2.2870	6.7382
51	08	69	127	2.2869	88
52	04	59	159	7	94
53	01	49	191	5	6.7400
54	8.5086097	39	223	3	05
55	94	29	254	1	11
56	91	19	286	2.2859	17
57	87	09	318	7	23
58	84	8 5091699	350	5	29
59	80	89	382	3	35
60	8.5086077	8.5091679	1.71414	2.2851	6.7441

LATITUDE 64°

Lat.	log **A** diff. 1″ = −0.05	log **B** diff. 1″ = −0.16	log **C** diff. 1″ = +0.54	log **D** diff. 1″ = −0.03	log **E** diff. 1″ = +0.10
° ′					
64 00	8.5086077	8.5091679	1.71414	2.2851	6.7441
1	74	69	446	2.2849	47
2	70	59	478	7	53
3	67	49	510	5	59
4	64	39	542	3	65
5	60	29	574	1	71
6	57	19	606	2.2839	77
7	54	09	638	7	83
8	51	8.5091599	670	5	89
9	47	89	702	3	95
10	8.5086044	8.5091579	1.71734	2.2831	6.7501
11	41	69	766	2.2829	07
12	37	59	798	7	13
13	34	49	830	5	19
14	31	39	862	3	24
15	27	30	894	1	30
16	24	20	927	2.2819	36
17	21	10	959	7	42
18	18	00	991	5	48
19	14	8.5091490	1.72023	3	54
20	8.5086011	8.5091480	1.72055	2.2811	6.7560
21	08	70	088	2.2809	66
22	04	60	120	7	72
23	01	50	152	5	78
24	8.5085998	40	184	3	84
25	94	31	217	1	91
26	91	21	249	2.2799	97
27	88	11	281	7	6.7603
28	85	01	314	5	09
29	81	8.5091391	346	3	15
30	8.5085978	8.5091381	1.72378	2.2791	6.7621
31	75	71	411	2.2789	27
32	71	61	443	7	33
33	68	52	476	5	39
34	65	42	508	3	45
35	61	32	541	1	51
36	58	22	573	2.2779	57
37	55	12	606	7	63
38	52	03	638	5	69
39	48	8.5091293	670	3	75
40	8.5085945	8.5091283	1.72703	2.2770	6.7681
41	42	73	736	2.2768	87
42	38	63	768	6	93
43	35	54	801	4	99
44	32	44	833	2	6.7706
45	28	34	866	0	12
46	25	24	899	2.2758	18
47	22	14	931	6	24
48	19	05	964	4	30
49	15	8.5091195	996	2	36
50	8.5085912	8.5091185	1.73029	2.2750	6.7742
51	09	75	062	2.2748	48
52	06	65	095	6	54
53	02	55	127	3	60
54	8.5085899	46	160	1	67
55	96	36	193	2.2739	73
56	93	26	226	7	79
57	90	16	258	5	85
58	86	07	291	3	91
59	83	8.5091097	324	1	97
60	8.5085880	8.5091087	1.73357	2.2729	6.7803

TABLE OF CORRECTIONS TO LONGITUDE FOR DIFFERENCE IN ARC AND SINE.

Log K (−)	Log difference.	Log d M (+)	Log K (−)	Log difference.	Log d M (+)	Log K (−)	Log difference.	Log d M (+)
3.871	0.0000001	2.380	4.732	0.0000052	3.241	5.033	0.0000206	3.542
3.970	02	2.479	4.746	056	3.255	5.040	213	3.549
4.115	03	2.624	4.761	059	3.270	5.047	221	3.556
4.171	04	2.680	4.774	063	3.283	5.054	228	3.563
4.221	05	2.730	4.788	067	3.297	5.062	236	3.571
4.268	06	2.777	4.801	071	3.310	5.068	243	3.577
4.292	07	2.801	4.813	075	3.322	5.075	251	3.584
4.309	08	2.818	4.825	080	3.334	5.082	259	3.591
4.320	09	2.839	4.834	084	3.343	5.088	267	3.597
4.361	10	2.870	4.849	089	3.358	5.095	275	3.604
4.383	11	2.892	4.860	094	3.369	5.102	284	3.611
4.415	12	2.924	4.871	098	3.380	5.108	292	3.617
4.430	13	2.939	4.882	103	3.391	5.114	300	3.623
4.445	14	2.954	4.892	108	3.401	5.120	309	3.629
4.459	15	2.968	4.903	114	3.412	5.126	318	3.635
4.473	16	2.982	4.913	119	3.422	5.132	327	3.641
4.487	17	2.996	4.922	124	3.431	5.138	336	3.647
4.500	18	3.009	4.932	130	3.441	5.144	345	3.653
4.524	20	3.033	4.941	136	3.450	5.150	354	3.659
4.548	23	3.057	4.950	142	3.459	5.156	364	3.665
4.570	25	3.079	4.959	147	3.468	5.161	373	3.670
4.591	27	3.100	4.968	153	3.477	5.167	383	3.676
4.612	30	3.121	4.976	160	3.485	5.172	392	3.681
4.631	33	3.140	4.985	166	3.494	5.178	402	3.687
4.649	36	3.158	4.993	172	3.502	5.183	412	3.692
4.667	39	3.176	5.002	179	3.511	5.188	422	3.697
4.684	42	3.193	5.010	186	3.519	5.193	433	3.702
4.701	45	3.210	5.017	192	3.526	5.199	443	3.708
4.716	48	3.225	5.025	199	3.534	5.204	453	3.713

TABLE OF VALUES OF LOG $\frac{1}{\cos \frac{1}{2} d L}$

$d L$	$\log \frac{1}{\cos \frac{1}{2} d L}$	$d L$	$\log \frac{1}{\cos \frac{1}{2} d L}$	$d L$	$\log \frac{1}{\cos \frac{1}{2} d L}$	$d L$	$\log \frac{1}{\cos \frac{1}{2} d L}$	$d L$	$\log \frac{1}{\cos \frac{1}{2} d L}$
′		′		′		′		′	
10	0.000000	28	0.000004	46	0.000010	64	0.000019	82	0.000031
11	1	29	4	47	10	65	19	83	32
12	1	30	4	48	11	66	20	84	32
13	1	31	4	49	11	67	21	85	33
14	1	32	5	50	11	68	21	86	34
15	1	33	5	51	12	69	22	87	35
16	1	34	5	52	12	70	22	88	36
17	1	35	6	53	13	71	23	89	36
18	1	36	6	54	13	72	24	90	37
19	2	37	6	55	14	73	24	91	38
20	2	38	7	56	14	74	25	92	39
21	2	39	7	57	15	75	26	93	40
22	2	40	7	58	15	76	26	94	41
23	2	41	8	59	16	77	27	95	41
24	3	42	8	60	16	78	28	96	42
25	3	43	8	61	17	79	29	97	43
26	3	44	9	62	18	80	29	98	44
27	3	45	9	63	18	81	30	99	45

SUBSIDIARY TABLE FOR REFERRING VALUES OF COEFFICIENTS A, B, C, D, E FROM BESSEL'S TO CLARKE'S ELLIPSOID.

Lat.	From log **A** subtract.	From log **B** subtract.	From log **C** subtract.	To log **D** add.	From log **E** subtract.
°					
23	0.0000582	0.0000233	0.00008	0.0061	0.0001
24	584	241	08	61	1
25	587	249	08	61	1
26	590	258	08	61	1
27	593	266	09	61	1
28	596	274	09	61	1
29	599	283	09	61	1
30	602	293	09	61	1
31	605	302	09	61	1
32	609	312	09	61	1
33	612	321	09	61	1
34	615	331	09	61	1
35	619	342	10	61	1
36	622	352	10	61	1
37	625	362	10	61	1
38	629	372	10	61	1
39	632	383	10	61	1
40	636	393	10	61	1
41	639	404	10	61	1
42	643	415	11	61	1
43	647	425	11	61	1
44	650	436	11	61	1
45	654	447	11	61	1
46	657	458	11	61	1
47	661	468	11	61	1
48	664	479	11	61	1
49	668	490	12	61	1
50	672	501	12	61	1
51	675	511	12	61	1
52	678	521	12	61	1
53	681	531	12	61	1
54	685	541	12	61	1
55	688	551	12	61	1
56	692	561	12	61	1
57	695	571	13	61	1
58	699	581	13	61	1
59	702	590	13	61	1
60	705	600	13	61	1
61	708	609	13	61	1
62	711	618	13	61	1
63	714	627	13	61	1
64	717	636	14	61	1
65	720	645	14	61	1

TABLE OF LOG F.

Lat.	Log **F**	Lat.	Log **F**	Lat.	Log **F**	Lat.	Log **F**
°		°		°		°	
23	7.812	34	7.877	45	7.840	56	7.706
24	23	35	77	46	32	57	7.688
25	32	36	77	47	24	58	69
26	41	37	76	48	14	59	49
27	49	38	74	49	04	60	27
28	55	39	72	50	7.792	61	05
29	61	40	69	51	80	62	7.581
30	66	41	64	52	67	63	56
31	70	42	60	53	53	64	29
32	73	43	54	54	38	65	01
33	75	44	48	55	23		

AUXILIARY TABLES FOR CONVERTING ARCS OF THE BESSEL ELLIPSOID INTO ARCS OF THE CLARKE ELLIPSOID.

[All corrections are negative.]

	Corrections to *d M*.						Arguments *L′* and *d M*.						
d M	60′	50′	40′	30′	20′	10′	60″	50″	40″	30″	20″	10″	5″
Lat. °	″	″	″	″	″	″	″	″	″	″	″	″	″
23	0.481	0.401	0.320	0.240	0.160	0.080	0.008	0.006	0.005	0.004	0.003	0.001	0.0006
24	.484	.403	.322	.242	.161	.080	.008	.006	.005	.004	.003	.001	.0006
25	.486	.405	.324	.243	.162	.081	.008	.006	.005	.004	.003	.001	.0006
26	.489	.407	.326	.245	.163	.081	.008	.006	.005	.004	.003	.001	.0006
27	.491	.409	.327	.246	.164	.082	.008	.006	.005	.004	.003	.001	.0006
28	.494	.411	.329	.247	.165	.082	.008	.007	.005	.004	.003	.001	.0006
29	.496	.413	.330	.248	.166	.083	.008	.007	.005	.004	.003	.001	.0006
30	.497	.416	.332	.250	.167	.083	.008	.007	.005	.004	.003	.001	.0006
31	.502	.418	.334	.251	.168	.084	.008	.007	.006	.004	.003	.001	.0006
32	.505	.420	.336	.253	.169	.084	.008	.007	.006	.004	.003	.001	.0006
33	.507	.422	.338	.254	.169	.085	.008	.007	.006	.004	.003	.001	.0006
34	.510	.425	.340	.255	.170	.085	.008	.007	.006	.004	.003	.001	.0006
35	.513	.427	.342	.256	.171	.086	.008	.007	.006	.004	.003	.001	.0006
36	.516	.430	.342	.258	.172	.086	.009	.007	.006	.004	.003	.001	.0006
37	.518	.432	.345	.259	.173	.087	.009	.007	.006	.004	.003	.001	.0007
38	.521	.434	.347	.261	.174	.087	.009	.007	.006	.004	.003	.001	.0007
39	.524	.436	.349	.262	.175	.088	.009	.007	.006	.004	.003	.001	.0007
40	.527	.439	.351	.264	.176	.088	.009	.007	.006	.004	.003	.001	.0007
41	.530	.441	.353	.265	.177	.089	.009	.007	.006	.004	.003	.001	.0007
42	.533	.444	.355	.267	.178	.089	.009	.007	.006	.004	.003	.001	.0007
43	.536	.446	.357	.268	.179	.090	.009	.007	.006	.004	.003	.001	.0007
44	.539	.449	.359	.270	.180	.090	.009	.008	.006	.005	.003	.001	.0007
45	0.542	0.451	0.361	0.271	0.181	0.091	0.009	0.008	0.006	0.005	0.003	0.001	0.0007

	Corrections to *d L*						Arguments $\frac{L+L'}{2}$ and *d L*						
d Z	60′	50′	40′	30′	20′	10′	60″	50″	40″	30″	20″	10″	5″
Lat. °	″	″	″	″	″	″	″	″	″	″	″	″	″
23	0.193	0.160	0.129	0.096	0.064	0.032	0.003	0.003	0.002	0.002	0.001	0.001	0.0003
24	.200	.165	.133	.099	.066	.033	.003	.003	.002	.002	.001	.001	.0003
25	.206	.171	.138	.103	.068	.034	.003	.003	.002	.002	.001	.001	.0003
26	.213	.177	.142	.106	.070	.035	.003	.003	.002	.002	.001	.001	.0003
27	.220	.183	.147	.110	.073	.037	.004	.003	.002	.002	.001	.001	.0003
28	.227	.189	.151	.113	.075	.038	.004	.003	.002	.002	.001	.001	.0003
29	.234	.196	.156	.117	.078	.039	.004	.003	.002	.002	.001	.001	.0003
30	.242	.202	.161	.121	.080	.040	.004	.003	.002	.002	.001	.001	.0003
31	.250	.209	.167	.125	.083	.042	.004	.003	.003	.002	.001	.001	.0004
32	.258	.216	.172	.129	.086	.043	.004	.003	.003	.002	.001	.001	.0004
33	.267	.223	.178	.133	.089	.045	.005	.003	.003	.002	.002	.001	.0004
34	.275	.230	.184	.137	.091	.046	.005	.003	.003	.002	.002	.001	.0004
35	.283	.237	.190	.141	.094	.047	.005	.004	.003	.002	.002	.001	.0004
36	.291	.243	.195	.145	.097	.048	.005	.004	.003	.002	.002	.001	.0004
37	.300	.250	.201	.150	.100	.050	.005	.004	.003	.002	.002	.001	.0004
38	.308	.257	.206	.154	.103	.051	.005	.004	.003	.002	.002	.001	.0004
39	.317	.264	.212	.158	.106	.053	.005	.004	.004	.003	.002	.001	.0004
40	.325	.271	.217	.162	.108	.054	.005	.004	.004	.003	.002	.001	.0005
41	.334	.278	.223	.167	.111	.056	.006	.004	.004	.003	.002	.001	.0005
42	.343	.286	.229	.171	.114	.057	.006	.004	.004	.003	.002	.001	.0005
43	.352	.294	.236	.176	.117	.059	.006	.005	.004	.003	.002	.001	.0005
44	.362	.302	.242	.181	.120	.060	.006	.005	.004	.003	.002	.001	.0005
45	0.372	0.310	0.249	0.186	0.124	0.062	0.006	0.005	0.004	0.003	0.002	0.001	0.0005

FORMULA AND TABLE FOR COMPUTING THE SPHERICAL EXCESS OF TRIANGLES.

In every spherical triangle the excess of the sum of the three angles over 180° bears the same ratio to eight right angles as the area of the triangle bears to that of the whole sphere. Putting r for radius, ε for the excess, we have $\frac{\varepsilon}{4\pi} = \frac{area}{4 r^2 \pi}$, hence $\varepsilon = \frac{area}{r^2}$. In order to express ε in seconds of arc, we must divide the expression by sin 1″. The area of the triangle, when it is small in relation to the whole sphere, as is the case in all geodesic triangles, may be expressed with sufficient accuracy for this purpose by $\frac{1}{2}$ A B sin c, where A B are two sides, and c the included angle. We have then

$$\varepsilon = \frac{\mathrm{A\,B} \sin c}{2 r^2 \sin 1''}$$

In estimating ε in a triangle on the terrestrial spheroid, we can refer it to an osculating sphere, the radius of which is taken as the mean of the radii of curvature in the meridian and prime vertical at the center of the triangles. These are respectively—

$$\mathrm{R} = \frac{a\,(1 - e^2)}{(1 - e^2 \sin^2 \mathrm{L})^{\frac{3}{2}}}, \qquad \mathrm{N} = \frac{a}{(1 - e^2 \sin^2 \mathrm{L})^{\frac{1}{2}}}$$

using the notation of the L, M, Z formulæ.

The mean of these two expressions developed, but embracing only terms below the fourth power of e, is $\frac{1}{2}(\mathrm{R} + \mathrm{N}) = a\,(1 - \frac{1}{4} e^2 \cos 2\,\mathrm{L} + \ldots)$

We have, therefore, for the spheroidal triangle,

$$\varepsilon = \frac{\mathrm{A\,B} \sin c}{2\,a^2\,(1 - \frac{1}{4} e^2 \cos 2\,\mathrm{L})^2 \sin 1''}$$

for which we write $\varepsilon = \mathrm{A\,B} \sin c \times m$, and tabulate the logarithms of $m = \frac{1}{2\,a^2\,(1 - \frac{1}{4} e^2 \cos 2\,\mathrm{L})^2 \sin 1''}$, for different latitudes.

TABLE OF LOG m.

Latitude.	Log m.	Latitude.	Log m.	Latitude.	Log m.	Latitude.	Log m.
° ′		° ′		° ′		° ′	
24 00	1.40596	31 30	1.40533	39 00	1.40461	46 30	1.40385
24 30	592	32 00	528	39 30	456	47 00	380
25 00	588	32 30	524	40 00	451	47 30	375
25 30	584	33 00	519	40 30	446	48 00	369
26 00	580	33 30	514	41 00	441	48 30	364
26 30	576	34 00	509	41 30	436	49 00	359
27 00	572	34 30	505	42 00	431	49 30	354
27 30	568	35 00	500	42 30	426	50 00	349
28 00	564	35 30	495	43 00	420	50 30	344
28 30	559	36 00	491	43 30	415	51 00	339
29 00	555	36 30	486	44 00	410	51 30	334
29 30	551	37 00	481	44 30	405	52 00	329
30 00	547	37 30	476	45 00	400	52 30	324
30 30	542	38 00	471	45 30	395	53 00	319
31 00	1.40537	38 30	1.40466	46 00	1.40390	53 30	1.40314

The above table is computed for Clarke's spheroid; to refer it to Bessel's spheroid, increase log m in the 5th place of decimals

by 9 for latitude 25°	by 10 for latitude 40°
by 9 for latitude 30°	by 11 for latitude 45°
by 10 for latitude 35°	by 12 for latitude 50°

APPENDIX No. 20.

METEOROLOGICAL RESEARCHES FOR THE USE OF THE COAST PILOT.

PREFATORY NOTE.

UNITED STATES COAST SURVEY OFFICE,
Washington, D. C., July 21, 1877.

The great storms which yearly traverse with terrible energy some portion of the vast extent of sea-coast that bounds the United States on the Atlantic and Pacific Oceans and the Gulf of Mexico have caused in the aggregate the loss of many thousands of lives and the destruction of an immense amount of property.

The most violent of these storms are the cyclones that originate commonly in the Atlantic Ocean near the equator. They pass over the West Indies, curve around by the Gulf of Mexico and Florida, and then sweep the entire coast of the Atlantic in a northeasterly direction.

The frequency of recurrence, and the marked force exerted along the same general course, suggest that these cyclones result from the operations of laws that control the general motions of the atmosphere, and that some understanding in regard to the cause and time of their occurrence might be gained by research, extended so as to include an area commensurate with the developed phenomena; but, until now, it is believed that no attempt directed to that end has been made. Any knowledge in advance respecting the direction and rate of motion of these storms would be of incalculable benefit to commerce and navigation, as well as to the people living along the sea-coasts. Their investigation has, therefore, been undertaken in the hope that the exact knowledge of the configuration of the coast and of its dangers, given to the mariner in the Coast Pilot, may in time be supplemented by information concerning the atmospheric disturbances to which the same region is subject. Mr. William Ferrel, to whom this discussion has been intrusted, and whose previous studies and special ability peculiarly qualify him for the proposed research, presents, in the following paper, the results of an investigation of the mechanics and the general motions of the atmosphere. This preliminary inquiry will be followed by his investigation of the effects of various disturbances that are local, as compared with those upon which general motions depend. Such disturbances give rise to local cyclones, due to unequal distributions of temperature in the northern and southern hemispheres. It will be shown also that local disturbances of equilibrium are the occasion of progressive cyclones.

The principles and results developed in the leading part of the discussion will, in a separate paper, be applied for perfecting the formulæ and methods to be used in the determination of barometric heights; and, as all the general principles applicable to atmospheric motions probably apply also to those of the ocean, the discussion will be supplemented by a chapter on the subject of ocean currents.

These researches will embody conclusions from the most important parts of a memoir published by Mr. Ferrel in 1859 and 1860 in the "Mathematical Monthly." The memoir appeared necessarily as small detached papers, separated by other matter, in two volumes of that journal, and hence the views of the author attracted little notice until extracts from his memoir were quoted in the publications of the United States Signal Service. The reader of the first paper by Mr. Ferrel upon this subject will notice a few slight changes; but it was to be expected that, in a matter so complex, additional years of study would offer both new and improved views.

CARLILE P. PATTERSON,
Superintendent.

PART I.

ON THE MECHANICS AND GENERAL MOTIONS OF THE ATMOSPHERE.

CHAPTER I.

GENERAL EQUATIONS OF THE MOTIONS AND THE PRESSURE OF THE ATMOSPHERE.

1. In making out equations of condition for the motions and pressure of the atmosphere or the sea, where the part under consideration comprises the whole or a considerable part of the earth's surface, it is very important that the rotation of the earth on its axis should be taken into account. This can be most conveniently done by referring each particle at any time to three rectangular co-ordinates whose directions are fixed in space, and thus making out equations between the motions, forces, and pressures for each of these directions. These co-ordinates thus become a function of the earth's rotation and the motion of the particle relatively to the earth's surface; and by transforming the rectangular to polar co-ordinates, and expressing the equations in functions of the latter, we obtain equations containing very important terms, depending upon the earth's rotation on its axis.

2. Let x, y, and z be three rectangular co-ordinates having their origin at the center of the earth, x corresponding with the axis of rotation; also let—

$V =$ the potential of the attractive force of the earth;
$P =$ the pressure of the fluid; and
$k =$ its density:

then $D_x V$, $D_y V$, and $D_z V$ are the accelerating forces arising from the earth's attraction, and $\frac{1}{k} D_x P$, $\frac{1}{k} D^y P$, and $\frac{1}{k} D_z P$ those arising from the pressure of the fluid in the reverse directions respectively of x, y, and z; and hence we have, for the equations of the absolute motions of the fluid, regarding the center of the earth at rest,—

$$(1) \quad \ldots\ldots\ldots\ldots \quad \begin{cases} D_t^2 x + D_x V + \frac{1}{k} D_x P = 0 \\ D_t^2 y + D_y V + \frac{1}{k} D_y P = 0 \\ D_t^2 z + D_z V + \frac{1}{k} D_z P = 0 \end{cases}$$

Putting $P = 0$, these become the equations of a projectile.

3. Let—

$r =$ the distance from the earth's center;
$\theta =$ the polar distance;
$\varphi =$ the longitude;
$n =$ the angular velocity of the earth's rotation on its axis.

We then have—

$$(2) \quad \ldots\ldots\ldots \quad \begin{cases} x = r \cos \theta \\ y = r \sin \theta \cos (n t + \varphi) = r \sin \theta \cos \omega \\ z = r \sin \theta \sin (n t + \varphi) = r \sin \theta \sin \omega \end{cases}$$

by putting, for brevity, $n t + \varphi = \omega$, and making the origin of t such as to make $\sin (n t + \varphi)$ vanish in the plane of x, y.

From these expressions of x, y, and z, we get—

$$D_t x = \cos \theta \, D_t r - r \sin \theta \, D_t \theta$$
$$D_t y = \sin \theta \cos \omega \, D_t r + r \cos \theta \cos \omega \, D_t \theta - r \sin \theta \sin \omega \, D_t \omega$$
$$D_t z = \sin \theta \sin \omega \, D_t r + r \cos \theta \sin \omega \, D_t \theta + r \sin \theta \cos \omega \, D_t \omega$$

Taking the second derivatives, we get—

$$(3)\left\{\begin{aligned}
D_t^2 x &= \cos\theta\, D_t^2 r - 2\sin\theta\, D_t r\, D_t\theta - r\cos\theta\,(D_t\theta)^2 - r\sin\theta\, D_t^2\theta \\
D_t^2 y &= \sin\theta\cos\omega\, D_t^2 r + 2\cos\theta\cos\omega\, D_t r\, D_t\theta - 2\sin\theta\sin\omega\, D_t r\, D_t\omega + r\cos\theta\cos\omega\, D_t^2\theta \\
&\quad - r\sin\theta\cos\omega(D_t\theta)^2 - 2r\cos\theta\sin\omega\, D_t\theta\, D_t\omega - r\sin\theta\sin\omega\, D_t^2\varphi - r\sin\theta\cos\omega\,(D_t\omega)^2 \\
D_t^2 z &= \sin\theta\sin\omega\, D_t^2 r + 2\cos\theta\sin\omega\, D_t r\, D_t\theta + 2\sin\theta\cos\omega\, D_t r\, D_t\omega + r\cos\theta\sin\omega\, D_t^2\theta \\
&\quad - r\sin\theta\sin\omega\,(D_t\theta)^2 + 2r\cos\theta\cos\omega\, D_t\theta\, D_t\omega + r\sin\theta\cos\omega\, D_t^2\varphi - r\sin\theta\sin\omega(D_t\omega)^2
\end{aligned}\right.$$

Since x, y, and z are functions of r, θ, and φ, we have—

$$(4) \quad \ldots\ldots \quad \left\{\begin{aligned}
D_x V &= D_r V \,.\, D_x r + D_\theta V \,.\, D_x\theta + D_\phi V \,.\, D_x\varphi \\
D_y V &= D_r V \,.\, D_y r + D_\theta V \,.\, D_y\theta + D_\phi V \,.\, D_y\varphi \\
D_z V &= D_r V \,.\, D_z r + D_\theta V \,.\, D\ \ \theta + D_\phi V \,.\, D_z\varphi
\end{aligned}\right.$$

We also have—

$$r^2 = x^2 + y^2 + z^2$$

$$\tan\theta = \frac{\sqrt{x^2 + y^2}}{x}$$

$$\tan\omega =$$

From these we get—

$$D_x r = \frac{x}{r} = \cos\theta$$

$$D_y r = \frac{y}{r} = \sin\theta\cos\omega$$

$$D_z r = \frac{z}{r} = \sin\theta\sin\omega$$

$$D_x\theta = -\frac{\sqrt{y^2+z^2}}{r^2} = -\frac{\sin\theta}{r}$$

$$D_y\theta = \frac{xy}{r^2\sqrt{y^2+z^2}} = \frac{\cos\theta\cos\omega}{r}$$

$$D_z\theta = \frac{xz}{r^2\sqrt{y^2+z^2}} = \frac{\cos\theta\sin\omega}{r}$$

$$D_x\varphi = 0$$

$$D_y\varphi = -\frac{z}{y^2+z^2} = \frac{\sin\omega}{r\sin\theta}$$

$$D_z\varphi = \frac{y}{y^2+z^2} = \frac{\cos\omega}{r\sin\theta}$$

By means of these equations, equations (4) give—

$$(5) \quad \ldots \quad \left\{\begin{aligned}
D_x V &= \cos\theta\, D_r V - \frac{\sin\theta}{r} D_\theta V \\
D_y V &= \sin\theta\cos\omega\, D\ \ V + \frac{\cos\theta\cos\omega}{r} D_\theta V - \frac{\sin\omega}{r\sin\theta} D_\phi V \\
D_z V &= \sin\theta\sin\omega\, D_r V + \frac{\cos\theta\sin\omega}{r} D_\theta V + \frac{\cos\omega}{r\sin\theta} D_\phi V
\end{aligned}\right.$$

By putting P for V in (4), we obtain in like manner—

$$(6)\ .\ .\ \begin{cases} D_x P = \cos\theta\ D_r P - \dfrac{\sin\theta}{r} D_\theta P \\ D_y P = \sin\theta\cos\omega\ D_r P + \dfrac{\cos\theta\cos\omega}{r} D_\theta P - \dfrac{\sin\omega}{r\sin\theta} D_\phi P \\ D_z P = \sin\theta\sin\omega\ D_r P + \dfrac{\cos\theta\sin\omega}{r} D_\theta P + \dfrac{\cos\omega}{r\sin\theta} D_\phi P \end{cases}$$

By substituting the values of the first members of equations (3), (5), and (6) in equations (1), and then multiplying both members of the equations respectively by $\cos\theta$, $\sin\theta\cos\omega$, and $\sin\theta\sin\omega$, and adding, we obtain the first of the following equations. Again, multiplying them respectively by $r\sin\theta$, $-r\cos\theta\cos\omega$, and $-r\cos\theta\sin\omega$, and adding, we obtain the second of those equations. Finally, multiplying the last two respectively by $r\sin\theta\sin\omega$ and $-r\sin\theta\cos\omega$, and adding, we get the last of the following equations:—

$$(7)\ \begin{cases} \dfrac{1}{k} D_r P = -D_t^2 r + r(D_t\theta)^2 + r\sin^2\theta\,(n + D_t\omega) D_t\varphi + r\,n^2\sin^2\theta - D_r V \\ \dfrac{1}{k} D_\theta P = -r^2 D_t^2\theta - 2r\,D_t r\,D_t\theta + r^2\sin\theta\cos\theta\,(n + D_t\omega)\,D_t\varphi + r^2 n^2\sin\theta\cos\theta - D_\theta V \\ \dfrac{1}{k} D_\phi P = -r^2\sin^2\theta\,D_t^2\varphi - 2r\sin^2\theta\,D_t r\,D_t\omega - 2r^2\sin\theta\cos\theta\,D_t\theta\,D_t\omega - D_\phi V \end{cases}$$

4. Let us now put—

h = the height above the earth's surface;
u = linear distance south;
v = linear distance east;
g = the accelerating force of gravity.

By regarding the cosine of the angle between the directions of r and h, which is extremely small, equal to unity, and neglecting the small terms depending upon the motions of the fluid, which are multiplied into the sine of the very small angle between the directions of r and h, and putting for $D_t\omega$ its equal, $n + D_t\varphi$, we shall have—

$$\begin{aligned} \frac{1}{k} D_h P &= -D_t^2 h + \frac{(D_t u)^2}{r} + \sin\theta\,(n + D_t\varphi)\,D_t v + r\,n^2\sin^2\theta - D_h V \\ \frac{1}{k} D_u P &= -D_t^2 u - 2\,D_t h\,D_t u + \cos\theta\,(2n + D_t\varphi)\,D_t v + r\,n^2\sin\theta\cos\theta - D_u V \\ \frac{1}{k} D_v P &= -D_t^2 v - 2\sin\theta\,(n + D_t\varphi)\,D_t h - 2\cos\theta\,(n + D_t\varphi)\,D_t u - D_v V \end{aligned}$$

5. In the case in which the fluid is at rest relatively to the earth's surface, we have

$$\begin{aligned} \frac{1}{k} D_h P &= r\,n^2\sin^2\theta - D_h V = -g \\ \frac{1}{k} D_u P &= r\,n^2\sin\theta\cos\theta - D_u V = 0 \\ \frac{1}{k} D_v P &= -D_v V = 0 \end{aligned}$$

Hence, in the case of the motions of the fluid, we have—

$$(8)\ .\ .\ \begin{cases} \dfrac{1}{k} D_h P = -D_t^2 h + \dfrac{(D_t u)^2}{r} + \sin\theta\,(n + D_t\varphi)\,D_t v - g \\ \dfrac{1}{k} D_u P = -D_t^2 u - 2\,D_t h\,D_t u + \cos\theta\,(2n + D_t\varphi)\,D_t v \\ \dfrac{1}{k} D_v P = -D_t^2 v - 2\sin\theta\,(n + D_t\varphi)\,D_t h - 2\cos\theta\,(n + D_t\varphi)\,D_t u \end{cases}$$

6. In these equations, there are several terms which are so small that they may be neglected in all cases without sensible error. The value of the term $D_t^2 h$ is of the same order, in comparison with g, as the rate with which an ascending or descending particle of air is accelerated or retarded in comparison with the rate with which a falling body in vacuum is accelerated; since, putting $P = 0$ in the first of the equations (8), we get $g = -D_t^2 h$. In all ordinary conditions of the air, the vertical velocities are so small, and these velocities are accelerated or retarded so gradually, that the value of $D_t^2 h$ corresponding to these accelerations or retardations, in comparison with the rate of acceleration of a falling body, is so small that it may be neglected. In the case of a tornado, the value of this term might be sensible through some part of the height of the atmosphere; but, as the velocity of an ascending body cannot be accelerated in one part of its ascent without being retarded in another part, the integration of this term through the whole height of the atmosphere would be naught, and hence it would not affect P at the surface of the earth.

If any part of the atmosphere has a vertical acceleration or retardation of velocity equal to g in 100 seconds, or a little less than two minutes, then the pressure or value of P arising from this part of the atmosphere is affected the one-hundredth part; and, in such a condition of the atmosphere, in determining heights from barometric pressure, the results would be seriously affected. But such conditions could only take place under some extraordinary disturbances of the atmosphere, when any such determinations would not be attempted. It is seen from the first of (8) that the pressure is diminished when the ascending velocity is accelerated or descending velocity retarded, and *vice versa.*

7. We have, neglecting $D_t \varphi$ in comparison with n,—

$$\frac{\sin^2 \theta (n + D_t \varphi) D_t v}{g} = \frac{r \sin^2 \theta \, n \, D_t \varphi}{g} = \frac{r n^2}{g} \cdot \frac{D_t \varphi}{n} \sin^2 \theta = \frac{1}{289} \sin^2 \theta \frac{D_t \varphi}{n}$$

But $D_t \varphi$, the angular eastward motion of the air relatively to the earth's surface, is always very small in comparison with n, and hence, even at the earth's equator, where $\sin^2 \theta = 1$, the ratio between $\sin^2 \theta \, (n + D_t \varphi) \, D_t v$ and g is extremely small, and the former may in all cases be neglected in connection with the latter. The value of the term $\frac{(D_t u)^2}{r}$ is evidently very much smaller than $\sin^2 \theta \, (n + D_t \varphi \, D_t v$, and hence its effect is always entirely insensible.

In the last two of equations (8), the terms containing $D_t h$ as a factor may both be neglected in comparison with the terms which follow them, since the vertical velocity $D_t h$ is always very much smaller than the horizontal velocities $D_t u$ or $D_t v$, where these latter are such as to give a sensible value to the terms containing them as factors.

8. The density of dry air is as the pressure and inversely as the amount of absolute temperature. But the atmosphere always contains a certain amount of aqueous vapor which is lighter than air, and affects the density of the atmosphere in proportion to the amount of this vapor contained in it. This effect is expressed by $(1+f(e))$ in the denominator of the expression for the density, in which e is the relative amount of aqueous vapor contained in the air. We therefore put—

$$(9) \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad k = a \, P$$

in which, putting a_0 for the value of a when $t = 0$ and $e = 0$,—

$$(10) \quad . \; . \; . \; . \quad a = \frac{273^\circ}{(273^\circ + t)(1 + f(e))} a_0 = \frac{1}{(1 + 0.3663 \, t)(1 + f(e))} a_0$$

The average value of e varies with the temperature, but is very different at different times and in different localities for the same temperature. As an average value of $f(e)$ for all localities and seasons, we can put—

$$f(e) = 0.00154 + 0.000341 \, t^*$$

With this value of $f(e)$, we get—

$$(11) \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad a = \frac{a_0}{1.00154 + 0.004 \, t}$$

* See a paper by Dr. J. Hann, entitled "Zur barometrischen Höhenmessung," in "Band LXXIV der Sitzb. der kaiserlichen Akademie der Wissenschaften."

This latter expression of a may be used in all cases in which the preceding equations are applied to the atmosphere generally, in which local and temporary deviations must be neglected; but, in local applications, the former must be used, the value of e being determined from observation for the particular time and locality.

9. So far we have neglected to consider the effect of friction, which is an important element entering into equations where the motions of fluids, either elastic or inelastic, are concerned, and one which is most difficult to treat. In the preceding equations, therefore, we must have a term to represent the resistance which each particle suffers from friction, and this term cannot be expressed by any function of the velocity simply, as is sometimes supposed, but it depends rather upon the differences in the velocities of the different strata, and upon the differences of pressure. If a stratum lie between two other strata, all having the same velocity, it suffers no resistance from friction, however great the velocity may be; and the same is the case where the relative velocities of the strata are such that the action of the stratum above upon the intermediate stratum is exactly equal to the reaction of the lower one upon it in the contrary direction. This may require the relative velocities of the different strata to be different on account of the differences in the amount of pressure, and it, no doubt, requires them to increase as the pressure diminishes, that is, with the height. The amount of resistance, therefore, which any particle suffers, requiring extraneous forces to overcome, is generally an unknown quantity, and all that we can do, therefore, is to introduce unknown functions into the equations representing the resistances from friction in the directions of the co-ordinates, and leave these to be determined approximately, where it can be done, from a comparison of the final results deduced from the equations with observation. If we, therefore, put F_u and F_v for the forces acting in the directions respectively of u and v necessary to overcome the resistances of friction, and substitute for k its value in (9), we get from (8), neglecting the insensible terms pointed out in §§ 6 and 7,—

$$(12) \quad \ldots \quad \begin{cases} D_h \log P = -g\,a \\ D_u \log P = -a\,D_t^2 u + a \cos\theta\,(2n + D_t\varphi)\,D_t v - a\,F_u \\ D_v \log P = -a\,D_t^2 v - 2\,a\cos\theta\,(n + D_t\varphi)\,D_t u - a\,F_v \end{cases}$$

In the case of a homogeneous fluid, it is readily seen that we must put P for log P and k instead of a.

The value of g is nearly constant; but, when great accuracy is required, it must be regarded as a function of h and θ, and we may put—

$$(13) \quad \ldots\ldots\ldots \quad g = g'\left(1 - \frac{2h}{r} + 0.00284 \cos 2\,\theta\right)$$

in which g' is the value of g at the sea-level and on the parallel of 45°.

10. By regarding g as independent of h, equation (12) gives, by integration,—

$$(14) \ldots \log P' - \log P = a'\Big(g\,h + f(h)\Big) + a'\int_u \Big(D_t^2 u - \cos\theta\,(2n + D_t\varphi)\,D_t v + F_u\Big)$$
$$+\, a \int_v \Big(D_t v + 2\cos\theta\,(n + D_t\varphi)\,D_t u + F_v\Big)$$

in which P′ and a' are the values of P and a respectively at the earth's surface, and $f(h)$ is a small function of h depending upon the decrease of temperature with the height, which may always be neglected, especially when h is small, except in accurate hypsometrical determinations. Where common tabular logarithms are used, the last number of this equation must be multiplied into the modulus $M = 0.4342945$.

The preceding expression gives the difference of the pressure between any two assumed points. If these two points are in the same vertical, the terms depending upon $D_t u$ and $D_t v$ vanish, and the expression is confined to the first term; but, if these points are in verticals a considerable distance apart, the integration of the last two terms, depending mostly upon the earth's rotation and the motions of the atmosphere relative to the earth's surface, may give a considerable difference of pressure at the sea-level, or for any two assumed points at equal heights above it.

11. Where P and P′ are in the same vertical, we get from (14), by neglecting the small term $f(h)$ in connection with $g\,h$, and regarding g constant,—

$$\begin{aligned} D_u \log P' - D_u \log P &= g\,h\,D_u\,a' \\ D_v \log P' - D_v \log P &= g\,h\,D_v\,a' \end{aligned}$$

By means of these equations, we get from (12)—

$$(15)\quad \ldots \quad \begin{cases} \frac{1}{a'} D_u \log P' = -D_t^2\,u + \cos\theta\,(2\,n + D_t\,\varphi)\,D_t\,v - F_u + g\,h\,D_u \log a' \\ \frac{1}{a'} D_v \log P' = -D_t^2\,v - 2\cos\theta\,(n + D_t\,\varphi)\,D_t\,u - F_v + g\,h\,D_v \log a' \end{cases}$$

At sea-level, we have $h = 0$, and consequently the last term of these equations vanishes, and they then give the gradients of barometrical pressure in the directions of u and v, depending upon the motions of the atmosphere at the earth's surface, friction, inertia, and the earth's rotation on its axis. In this case, the small neglected function $f(h)$ also vanishes.

12. If we put h' for the value of h belonging to a stratum of the atmosphere of equal density, or pressure, we shall have, for this stratum, $D_u\,P = 0$ and $D_v\,P = 0$; and we get in this case from the first of (14), neglecting the small function $f(h)$ in comparison with $g\,h$,—

$$\begin{aligned} D_u \log P' &= g\,h'\,D_u\,a' + g\,a'\,D_u\,h' \\ D_v \log P' &= g\,h'\,D_v\,a' + g\,a'\,D_v\,h' \end{aligned}$$

With these equations, we get from (15), by putting $h = 0$,—

$$(16)\quad \ldots \quad \begin{cases} g\,D_u\,h' = -D_t^2\,u' + \cos\theta\,(2\,n + D_t\,\varphi)\,D\,v' - F_u' - g\,h'\,D_u' \log a' \\ g\,D_v\,h' = -D_t^2\,v' - 2\cos\theta\,(n + D_t\,\varphi)\,D_t\,u' - F_v' - g\,h'\,D_v' \log a' \end{cases}$$

in which u' and v' are the values of u and v at the earth's surface. These equations give the gradients of the strata of equal pressure in the directions of u and v; and, by integration, they give the differences of level of any two points in such a stratum. This, at the earth's surface, when $h' = 0$, depends simply upon the motions of the atmosphere at the earth's surface, friction, and inertia; but the last terms of these equations show that these gradients are increased or diminished, as the case may be, in proportion to the height.

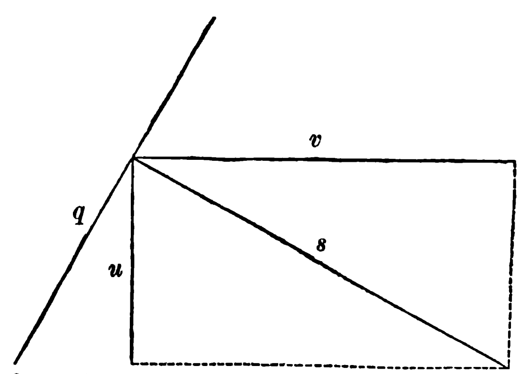
13. From (12) we get, for the part depending upon the earth's rotation,

$$\begin{aligned} D_u \log P &= 2\,a\,n\cos\theta\,D_t\,v \\ D_v \log P &= -2\,a\,n\cos\theta\,D_t\,u \end{aligned}$$

If we now put s for the resultant of u and v, and q a perpendicular to s on the right-hand side of the direction of motion, we shall have—

$$\begin{aligned} D_q \log P &= D_u \log P\,.\,D_q\,u + D_v \log P\,.\,D_q\,v \\ &= D_u \log P\,.\cos\frac{q}{u} - D_v \log P\,.\sin\frac{q}{u} \end{aligned}$$

$$D_t\,s = D_t\,u\sin\frac{q}{u} + D_t\,v\cos\frac{q}{u}$$



From these and the two preceding equations, we get—

$$(17)\quad \ldots \quad D_q \log P = 2\,a\,n\cos\theta\,D_t\,s$$

The direction of s is entirely arbitrary, and $D^t s$ represents velocity in that direction, and $D_q \log P$ represents an ascending gradient in the direction of q to the right of the direction of s, and consequently the force depending upon the earth's rotation which causes this gradient, expressed by the last member of (17), is a force acting in that direction, and is positive in the northern hemisphere, and the contrary in the southern, according to the sign

of cos θ. Hence, *in whatever direction a body moves upon the surface of the earth, there is a force arising from the earth's rotation which tends to deflect it to the right in the northern hemisphere, but to the left in the southern hemisphere.*

This important principle, useful in explaining so many of the relations between the motions and the barometric gradients of the atmosphere, was first published in my former paper on this subject in the "Mathematical Monthly" in the year 1860. It is a generalization of the principle upon which the theory of the trade winds has been based, according to which this deflecting force, arising from the earth's rotation, takes place only in the case of motions north or south. But, by the true and more general principle above, it is seen that this deflecting force is exactly the same for motions in all other directions.

Influenced by the usual theory upon this subject, observers have imagined that they have seen evidences of a tendency in rivers running north and south to wear away the banks, and also to deposit drift-wood on the right- rather than on the left-hand side, and likewise a tendency in the cars of railroads extending north and south to be thrown off the track on the right- rather than the left-hand side, while in the cases of rivers or of railroads extending in other directions no evidences of such effects could be seen. But we now know that if any sensible effects of this sort arise from this deflecting force in the case of rivers or of railroads running north or south, the very same effects must take place where they run in any other direction.

The amount of this force as deduced above, from the true principles of mechanics, is exactly double of that which has been obtained from the erroneous principle adopted by Hadley, and brought down through text-books to the present time. This latter principle assumes that the moving body in approaching or receding from the earth's axis must retain the same linear motion east or west, whereas, by the principle of the preservation of areas, which must hold in this case, the linear motion east or west must be increased in the former case and diminished in the latter in such proportion as to make the deflecting force double of that given by the principle of equal linear east or west motions for all distances from the earth's axis. This matter has been explained in detail in "Nature," vol. v, p. 384.

14. The accelerating force in the direction of q which is adequate to produce a gradient represented by $D_q P$ is—

$$(18)\quad \frac{1}{k} D_q P = \frac{1}{a} D_q \log P = 2 n \cos\theta\, D_t s = \frac{2\cos\theta}{r n} . r n^2 D_t s = \frac{2\cos\theta}{r n} . \frac{1}{289} g . D_t s = \frac{2\cos\theta}{289} . \frac{D_t s}{r n} . g$$

The coefficient of g in this expression shows the ratio between this deflecting force and the force of gravity.

Let us put at sea-level, on the parallel of 45°,—

$r = 6366252^{m}$	$\log r \;=\; 6.8038838$
$n = \dfrac{2\pi}{(23 \times 60 + 56)\, 60} = 0.000072924$	$\log n \;=\; -\,5.86287$
$g = 9^{m}.805307$	$\log g \;=\; 0.9914612$
$r n = 464^{m}.25$	$\log r n = 2.66675$

With $D_t s = 13.889$, which is equal to a velocity in the direction of s of 50^{km} per hour, and with $\theta = 45°$, corresponding to the parallel of 45°, we get $\frac{1}{6839} g$ for the accelerating force in the direction of q arising from the earth's rotation, and hence the lateral pressure of a body moving with the assumed velocity in any direction on that parallel is equal to $\frac{1}{6839}$ of its weight. In the southern hemisphere, where cos θ is negative, of course the lateral pressure is in the contrary direction, that is, to the left of the direction of motion. Where a body is free, this deflecting force produces motion in a curved line. In the case of a fluid, as air or water, this force causes a disturbance of the static level surface, and the amount of gradient resulting from it is expressed by the coefficient of g in (18). For instance, with the assumed velocity above and on the parallel of 45°, the gradient would be one meter in the distance of 6839 meters.

If a river has a velocity of 5^{km} per hour, the ascending gradient to the right of direction in the

northern hemisphere is one meter in 6839 meters; and hence, if the river is one kilometer in width, the water stands about $\frac{1}{68}$ of a meter higher on the right than on the left bank.

15. In the case of the atmosphere, in which the gradient is usually measured by the differences of barometric pressure, we get from (9) and (18) for this gradient—

$$(19) \quad \ldots\ldots\ldots\ldots \quad D_q P = 0.00014595 \, a \, P \cos\theta \, D_t s$$

In order to have a numerical expression of the gradient in terms of the pressure and temperature, and independent of the density, it is necessary to determine the value of a_0 in (11), from which we thus obtain the value of a corresponding to any given temperature t, and that of a' corresponding to the value of a at the earth's surface, which occurs in most of the preceding expressions, and of which, therefore, it is important to have a determination.

The value of a_0 is the value of a in (9) belonging to dry air, with the temperature at zero (32° F.). If we put l equal to the height of a homogeneous atmosphere of temperature 0°, and pressure, measured by the height of the barometrical column, of $0^m.76$, we have for such an atmosphere—

$$P = g \, k_0 \, l = g \, k' \times 0^m.76$$

in which k_0 is the density of dry air under the assumed pressure, and k' the density of mercury. Putting $k_0 = a_0 P$ (9), we get, since the heights of the homogeneous atmosphere and mercury are inversely as their densities—

$$1 = g \, a_0 \, l = g \, a_0 \frac{k'}{k_0} \times 0^m.76$$

With $k' = 13.6001$ and $k_0 = \frac{1^*}{772.9}$, we finally get—

$$(20) \quad \ldots\ldots\ldots\ldots \quad a_0 = \frac{1}{g \, l} = \frac{1}{g \times 7989^m}$$

With this value of a_0, we get from (11) the approximate value of a for any given temperature, to be used in (19) for determining the barometric gradient belonging to the deflecting force arising from the velocity $D_t s$. For the temperature of 0°, a in (19) becomes a_0; and, with the preceding value of a_0, we get in this case—

$$(21) \quad \ldots\ldots\ldots\ldots \quad D_q P = 0.0000000014162 \cos\theta \, D_t s$$

in which $D_t s$ must be expressed in meters per second.

If we wish to express the gradients by the change in millimeters belonging to the distance of a mean degree of the meridian, equal 111111111 millimeters, we must multiply the second member above by 111111111, and then, representing the gradient by G, we get—

$$(21') \quad \ldots\ldots\ldots\ldots \quad G = 0.15893 \cos\theta \, D_t s$$

16. In many cases, it is necessary to have the equations of the motions and pressures in terms of polar co-ordinates, in which the pole does not coincide with the pole of the earth's axis.

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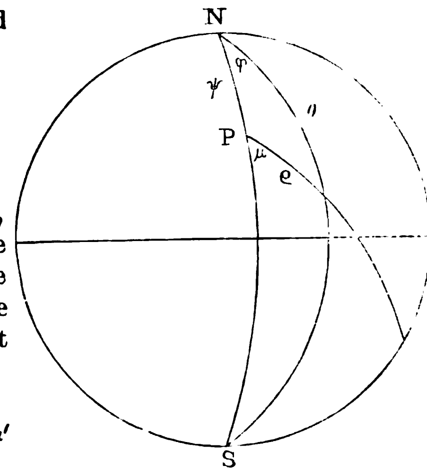
* Prof. F. A. P. Barnard, *Metric System*, p. 171, has obtained, from the average of the weights of a cubic inch of dry air given by several authorities, 0.0012228315 for the specific gravity of dry air at a temperature of 62° F. and a barometric pressure of 30 inches. This reduced to the temperature of 0° C. and barometric pressure of $0^m.760$ gives the value above.

Let—

ψ = the arc between the pole of the earth's axis and the new pole of the co ordinates;
ρ = the distance in arc from the new pole;
μ = the angle between ρ and the meridian;
u = linear distance in the direction of ρ; and
v = linear distance in a direction perpendicular to ρ.



In the case in which the earth has no rotation on its axis, the pole of the co-ordinates in the preceding equations can be taken at pleasure, and therefore, instead of N, the pole of the earth's axis in the annexed figure, we can put it at P, and hence by putting ρ, μ, u, and v for θ, φ, u, and v respectively, we get from (15) in this case, by putting $n = 0$,—

$$\frac{1}{a'} D_u \log P' = - D_t^2 u + \cos\varphi\, D_t\mu\, D_t v - F_u + g\,h\, D_u \log a'$$

$$\frac{1}{a'} D_v \log P' = - D_t^2 v - 2\cos\varphi\, D_t\mu\, D_t u - F_v + g\,h\, D_v \log a'$$

We must now add to these equations the terms arising from the deflecting forces depending upon the earth's rotation belonging to the velocities $D_t u$ and $D_t v$, which are forces in directions respectively perpendicular to u and v. From (17) we get, for the parts of $\frac{1}{a'} D_u \log P'$ and $\frac{1}{a'} D_v \log P'$,—

$$\frac{1}{a'} D_u \log P' = 2\,n \cos\theta\, D_t v$$

$$\frac{1}{a'} D_v \log P' = 2\,n \cos\theta\, D_t u$$

Adding the right-hand members of these equations to those of the two preceding ones, we get for the equations in the case in which the earth rotates on its axis—

$$(22) \;.\;.\; \begin{cases} \frac{1}{a'} D_u \log P' = - D_t^2 u + (2\,n \cos\theta + \cos\rho\, D_t\mu)\, D_t v - F_u + g\,h\, D_u \log a' \\ \frac{1}{a'} D_v \log P' = - D_t^2 v - 2\,(n \cos\theta + \cos\rho\, D_t\mu)\, D_t u - F_v + g\,h\, D_v \log a' \end{cases}$$

We have, from the trigonometrical relations of a spherical triangle,—

$$\cos\theta = \cos\psi \cos\rho - \sin\psi \sin\rho \cos\mu$$

Where the range of ρ is so small that we can neglect the second term of this expression in comparison with the first, and put $\cos\rho = 1$ without material error, (22) becomes—

$$(23) \;.\;.\; \begin{cases} \frac{1}{a'} D_u \log P' = - D_t^2 u + (2\,n \cos\psi + D_t\mu)\, D_t v - F_u + g\,h\, D_u \log a' \\ \frac{1}{a'} D_v \log P' = - D_t^2 v - 2\,(n \cos\psi + D_t\mu)\, D_t u - F_v + g\,h\, D_v \log a' \end{cases}$$

17. Besides the preceding equations (15) and (23) showing the relations between the motions and pressure of the fluid, there is still another condition, which must always be satisfied in the case of motions of the atmosphere, which is, that the volume of air which occupies any given space must be the same, and the amount of air directly proportional to its density, and the motions of the atmosphere must always be such as to satisfy these conditions. The mathematical expression of this condition in any case where such can be formed, is called the equation of continuity.

CHAPTER II.

THE TEMPERATURE AND PRESSURE OF THE ATMOSPHERE AT THE EARTH'S SURFACE OBTAINED FROM OBSERVATION.

18. In most of the equations of the preceding chapter there are found two functions, a' and P', which it is necessary to determine for all parts of the earth's surface from observation. It is seen from (11) that a is a function of t the temperature, a' being the value of a corresponding to the temperature of the atmosphere at the earth's surface. With the value of t, therefore, for all parts of the earth's surface, we obtain from (11) the expression of a' in a function of θ and φ, and consequently of u and v, from which we obtain the functions $D_u \log a'$ and $D_v \log a'$.

The general equations of motion and pressure of the atmosphere contained in the preceding chapter are of such a character, on account of their complexity, and the unknown friction terms entering into them, that they do not admit of a complete solution, and it is therefore important to obtain from observation as many as possible of the functions entering into those equations. If the general equations could be completely solved, we should need only the temperature from observation, and the solution of the equations would then give the atmospheric pressures for all parts of the earth belonging to this temperature, and we should not need the pressures from observation, except for a verification of theory. But as it is, we also need the observed pressures in the different parts of the earth's surface, in order to enable us to obtain other unknown quantities depending upon these pressures, which cannot be obtained from the solution of the equations.

The following tables, I and II, of approximate temperatures for the two extremes, January and July, have been obtained by interpolation from Buchan's Charts of Isothermal Lines, with some corrections first applied, to make them agree with recent observations. The authority for these corrections is derived mostly from the "Contributions to our Knowledge of the Meteorology of Cape Horn and the West Coast of South America," published by the authority of the Meteorological Committee of London. These contributions give temperatures generally from four to six degrees higher for these parts than those indicated by Buchan's isothermal lines for July, and three or four degrees higher than those indicated by his lines for January. As the temperature of the latitude of Cape Horn must be very nearly the same for all longitudes, the temperatures of the extreme southern latitudes in the following tables have been increased accordingly all around the globe. The last columns of these tables contain the means of the temperature for all the different longitudes. Although the numbers given for the different longitudes are only approximate, and may in some instances be considerably in error, yet the means of so many longitudes must give very nearly the averages of the different latitudes of the globe, and will be sufficiently accurate for our purpose. And the local variations of temperature independent of latitude will be only needed approximately for explaining in a general way the phenomena depending upon them, and not for any accurate comparisons of theory with observation.

TABLE I.—*Showing the approximate mean temperature in degrees of Fahrenheit for the differen of the earth's surface in*

JANUARY.

Latitude.	Longitudes west.																		
	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0
80	−33	−32	−32	−33	−34	−35	−37	−39	−40	−39	−36	−30	−24	−22	−20	−18	−15	−12	−10
70	−26	−24	−22	−23	−24	−26	−28	−30	−32	−31	−30	−23	−15	− 5	4	8	12	18	22
60	10	11	12	12	11	5	− 5	−13	−20	−24	−22	−16	0	12	20	28	36	36	34
50	40	40	40	40	40	36	32	22	10	5	0	5	10	26	38	42	44	42	38
40	50	49	50	51	50	50	46	42	36	32	30	32	38	48	54	56	54	52	48
30	60	59	58	57	58	57	56	54	54	54	54	58	62	66	66	66	64	62	60
20	72	71	70	69	68	66	66	66	66	70	72	71	74	74	74	74	74	74	74
10	76	76	76	76	76	76	76	76	76	76	78	78	78	76	76	78	80	82	85
0	80	80	80	80	80	80	80	80	82	82	82	82	82	81	80	80	80	80	80
−10	82	82	81	80	80	80	80	80	80	80	80	82	84	84	84	82	78	78	78
−20	78	78	78	78	78	77	76	76	76	76	78	80	82	82	80	78	76	75	74
−30	74	74	73	72	72	72	71	71	70	69	69	72	74	74	74	74	72	71	70
−40	64	64	64	64	64	62	62	62	62	62	62	64	66	67	68	68	66	62	62
−50	52	52	52	51	51	51	51	51	50	50	55	54	55	55	55	55	55	53	52
−60	39	39	39	38	38	38	38	38	37	37	38	40	41	42	42	42	42	41	39

Latitude.	Longitudes east.																	Mean.
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	°
80	−10	−10	−10	−10	−10	−10	−12	−15	−20	−24	−28	−32	−33	−34	−34	−34	−33	−25.0
70	25	18	5	− 6	−10	−10	−12	−15	−18	−22	−27	−32	−36	−38	−38	−36	−30	−15.5
60	30	24	16	10	6	0	− 4	− 8	−12	−16	−24	−30	−30	−24	−16	0	12	1.7
50	34	28	24	18	12	6	4	0	0	0	0	0	4	10	18	24	34	21.3
40	46	44	42	40	35	30	30	30	30	30	26	20	22	30	36	40	44	40.0
30	58	56	55	54	53	52	51	50	47	44	42	40	44	50	53	56	60	55.2
20	74	74	72	62	66	68	70	72	72	72	72	70	70	72	72	72	72	71.0
10	88	90	86	80	80	80	82	82	80	78	76	76	76	76	76	76	76	78.7
0	84	90	90	86	84	82	82	82	81	80	80	80	80	80	80	80	80	81.2
−10	86	90	90	86	84	82	82	82	82	82	82	82	82	82	82	82	82	82.2
−20	82	86	86	84	83	82	82	82	82	82	82	82	82	82	82	80	80	80.0
−30	76	78	78	78	78	78	78	76	74	74	73	72	72	72	72	72	74	73.4
−40	62	64	64	64	64	64	64	64	64	64	64	64	64	64	63	62	63	63.8
−50	52	52	51	51	51	51	51	51	51	51	51	51	51	50	50	50	50	52.0
−60	37	36	35	35	36	36	37	37	38	38	38	38	38	39	39	39	39	38.5

TABLE II.—*Showing the approximate temperature in degrees of Fahrenheit for the different parts of the earth's surface in*

JULY.

Latitude.	Longitudes west.																		
	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0
80	34	33	32	32	32	32	32	32	32	33	34	34	34	32	30	30	30	31	32
70	40	40	40	46	50	50	46	44	42	40	38	40	42	42	38	38	38	40	43
60	48	50	52	54	58	62	62	60	56	52	48	45	46	47	48	50	54	55	66
50	60	58	56	56	60	62	68	70	70	68	60	60	60	60	60	62	64	64	64
40	66	66	64	62	60	62	68	74	84	84	76	72	70	70	70	70	70	72	74
30	72	69	66	66	66	68	70	80	88	88	84	82	80	78	77	78	78	81	81
20	80	76	76	76	76	76	76	80	84	85	84	82	82	81	80	82	84	88	90
10	80	80	80	80	80	81	82	82	82	83	84	84	84	82	81	81	82	84	88
0	76	77	78	78	78	78	78	79	80	81	82	82	84	82	78	78	78	78	78
—10	74	74	74	73	75	74	73	74	75	74	75	76	76	75	74	74	74	74	74
—20	66	68	68	68	68	68	68	69	68	67	66	68	70	72	72	70	68	68	68
—30	60	60	60	60	60	60	60	60	60	59	58	58	60	64	64	64	64	66	62
—40	52	51	52	53	54	54	54	53	52	50	50	48	48	49	50	52	54	55	56
—50	45	45	45	45	45	44	43	43	43	43	43	43	43	44	45	45	45	45	45
—60	34	34	33	33	33	32	32	32	31	31	32	33	32	33	34	34	34	33	33

Latitude.	Longitudes east.																	Mean.
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	°
80	33	34	34	34	33	32	32	32	33	34	35	36	37	38	37	36	35	34.1
70	46	50	48	44	40	38	40	42	46	50	50	52	52	52	51	50	46	44.3
60	60	62	63	64	64	64	64	65	65	65	65	65	64	60	58	54	52	57.0
50	65	66	68	70	72	74	74	74	74	72	71	70	67	64	63	60	60	65.5
40	76	78	78	78	78	78	80	82	82	82	80	78	74	70	68	66	65	73.0
30	82	83	86	88	90	90	90	89	88	87	85	82	80	78	76	74	71	80.0
20	91	92	92	91	90	90	89	88	87	87	86	85	83	82	81	80	80	84.2
10	90	90	90	88	86	84	82	82	82	83	83	83	82	82	82	82	81	83.2
0	80	84	84	80	78	78	78	78	79	80	81	80	78	76	76	76	76	79.0
—10	78	80	80	78	77	76	76	76	76	76	76	76	75	74	74	74	73	75.2
—20	70	74	74	74	74	74	72	70	69	68	68	68	68	68	68	68	69	69.5
—30	61	60	60	60	60	60	60	60	60	60	59	58	56	54	56	58	59	60.1
—40	55	54	54	54	53	52	52	52	52	52	51	50	50	50	51	52	52	52.0
—50	45	45	45	45	44	43	43	43	42	41	41	41	41	41	41	42	43	43.5
—60	32	31	31	30	30	30	31	31	32	32	32	32	32	32	32	31	32	32.0

Tables III and IV give the approximate mean annual temperatures for each tenth degree of latitude and longitude and the approximate mean annual range of temperature, and likewise the means of all the longitudes. The former have been obtained by taking simply the mean of the extreme mean temperatures of January and July, and the latter by taking the differences of these extremes. Any one must be struck, from an inspection of Table IV, with the great differences between the mean annual ranges of temperature of the northern and southern hemispheres, arising from the unequal distribution of land and water in the two hemispheres.

TABLE III.—*Showing the approximate mean annual temperature in degrees of Fahrenheit for the different parts of the earth's surface.*

½ (January + July).

Latitude.	Longitudes west.																		
	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0
80	0	0	0	0	−1	−1	−2	−3	−4	−3	−1	2	5	5	5	6	8	10	11
70	7	8	9	11	13	12	9	7	5	4	4	8	13	19	21	23	25	29	32
60	29	30	32	33	35	34	29	24	18	14	13	14	23	29	34	39	45	45	45
50	50	49	48	48	50	49	47	46	40	36	30	32	35	43	49	52	54	53	51
40	53	57	57	56	56	57	57	58	60	58	53	52	54	59	62	63	62	62	56
30	66	64	62	61	61	61	62	67	71	71	69	70	71	72	72	72	71	72	71
20	76	74	73	72	72	71	71	73	75	82	78	77	78	77	77	78	79	81	82
10	78	78	78	78	78	78	79	79	79	80	81	81	81	80	80	80	81	83	86
0	78	78	79	79	79	79	79	80	81	81	82	82	83	82	79	79	79	79	79
−10	78	78	78	77	77	77	77	77	77	77	78	79	80	80	79	78	76	76	76
−20	73	73	73	73	73	73	72	72	72	72	72	74	76	77	76	74	72	72	71
−30	67	67	66	66	66	66	65	65	65	64	64	65	67	69	69	69	69	69	66
−40	58	58	58	58	59	58	58	58	57	56	56	56	57	58	59	60	60	59	59
−50	48	48	48	48	48	48	47	47	47	47	49	49	49	49	50	50	50	50	48
−60	36	36	36	36	35	35	35	35	34	34	35	37	37	37	38	38	38	37	36

Latitude.	Longitudes east.																	Mean.
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	°
80	11	12	12	12	12	11	10	8	6	5	4	2	2	2	2	1	1	4.5
70	35	34	27	19	15	14	14	13	14	14	12	10	8	7	6	7	8	14.4
60	45	43	40	37	35	32	30	28	26	25	21	17	17	18	21	27	32	29.3
50	50	47	46	44	42	40	39	37	37	36	35	35	35	37	40	42	47	43.4
40	61	61	60	59	57	54	55	56	56	56	53	49	48	50	52	53	54	56.5
30	70	70	70	71	71	71	71	70	68	66	64	61	62	64	65	65	65	67.6
20	82	83	82	80	78	79	79	80	80	80	79	78	76	77	77	76	76	77.6
10	89	90	88	84	83	82	82	82	81	80	80	80	79	79	79	79	78	81.0
0	82	87	87	83	81	80	80	80	80	80	80	80	79	78	78	78	78	80.1
−10	82	85	85	82	80	79	79	79	79	79	79	79	79	78	78	78	77	78.7
−20	76	80	80	79	79	78	77	76	75	75	75	75	75	75	75	75	74	74.7
−30	68	69	69	69	69	69	69	68	67	67	66	65	64	63	64	65	66	66.7
−40	58	59	59	59	59	59	58	58	58	58	58	57	57	57	57	57	57	57.9
−50	48	48	48	48	48	47	47	47	47	46	46	46	46	46	46	46	47	47.8
−60	35	33	33	33	33	34	33	33	33	34	35	35	35	34	34	34	35	35.3

TABLE IV.—*Showing the approximate mean annual range of temperature in degrees of Fahrenheit for the different parts of the earth's surface.*

(July – January.)

Latitude.	Longitudes west.																		
	180	170	160	150	140	130	120	110	100	90	80	70	60	50	40	30	20	10	0
80	67	65	64	65	66	67	69	71	72	72	70	64	58	54	50	48	45	43	42
70	66	64	62	69	74	76	74	74	74	71	68	63	57	47	34	30	26	22	21
60	38	40	40	42	47	57	67	73	76	76	70	61	46	35	28	22	18	19	22
50	20	18	16	16	20	26	36	48	60	63	60	55	50	34	22	20	20	22	26
40	16	17	14	11	8	10	22	32	48	52	46	40	32	22	16	14	16	20	26
30	12	10	8	9	10	13	16	26	34	34	30	24	18	12	11	12	14	19	21
20	8	5	6	7	8	9	10	15	18	15	12	11	8	7	6	8	10	14	16
10	4	4	4	4	4	5	6	6	6	7	6	6	6	6	5	3	2	2	3
0	– 4	– 3	– 2	– 2	– 2	– 2	– 2	– 1	– 2	– 1	0	0	2	1	– 2	– 2	– 2	– 2	– 2
–10	– 8	– 8	– 7	– 7	– 5	– 6	– 7	– 6	– 5	– 6	– 5	– 6	– 8	– 9	–10	– 8	– 4	– 4	– 4
–20	–10	–10	–10	–10	–10	– 9	– 8	– 7	– 8	– 9	–12	–12	–12	–10	– 8	– 8	– 8	– 7	– 6
–30	–14	–14	–13	–12	–12	–12	–11	–11	–10	–10	–11	–14	–14	–10	–10	–10	– 8	– 5	– 8
–40	–12	–13	–12	–11	–10	– 8	– 8	– 9	–10	–12	–12	–16	–18	–18	–18	–16	–12	– 7	– 6
–50	– 7	– 6	– 6	– 6	– 6	– 7	– 8	– 9	–10	–11	–12	–11	–11	–12	–11	–10	–10	– 8	– 7
–60	– 5	– 5	– 5	– 5	– 5	– 6	– 6	– 6	– 6	– 6	– 6	– 7	– 7	– 9	– 8	– 8	– 8	– 8	– 6

Latitude.	Longitudes east.																	Mean.
	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	°
80	43	44	44	44	43	42	44	47	53	58	63	68	70	72	71	70	68	59.1
70	21	32	43	50	50	48	52	57	64	72	77	84	88	90	89	86	76	59.8
60	30	38	47	54	58	64	68	73	77	81	89	95	94	84	74	54	40	55.3
50	31	38	44	52	60	68	70	74	74	72	71	70	63	54	45	36	26	44.2
40	30	34	36	38	43	48	50	52	52	52	54	58	52	40	32	26	21	33.0
30	24	27	31	34	37	38	39	39	41	43	43	42	36	28	23	18	11	24.8
20	17	18	20	23	24	22	19	16	15	15	14	15	13	10	9	8	8	13.2
10	2	0	4	8	6	4	0	0	2	5	7	7	6	6	6	6	5	4.5
0	– 4	– 6	– 6	– 6	– 6	– 4	– 4	– 4	– 2	0	1	0	– 2	– 4	– 4	– 4	– 4	– 2.2
–10	– 8	–10	–10	– 8	– 7	– 6	– 6	– 6	– 6	– 6	– 6	– 6	– 7	– 8	– 8	– 8	– 9	– 7.0
–20	–12	–12	–12	–10	– 9	– 8	–10	–12	–13	–14	–14	–14	–14	–14	–14	–12	–11	–10.5
–30	–15	–18	–18	–18	–18	–18	–18	–16	–14	–14	–14	–14	–16	–18	–16	–14	–15	–13.3
–40	– 7	–10	–10	–10	–11	–12	–12	–12	–12	–12	–13	–14	–14	–14	–12	–10	–11	–11.8
–50	– 7	– 7	– 6	– 6	– 7	– 8	– 8	– 8	– 9	–10	–10	–10	–10	– 9	– 9	– 8	– 7	– 8.5
–60	– 5	– 5	– 5	– 5	– 6	– 6	– 6	– 6	– 6	– 6	– 6	– 6	– 6	– 7	– 7	– 8	– 7	– 6.5

The numbers in Tables I and II being averages for the months of January and July, and not the extremes of the average mean daily temperature, the results of this table require a small correction, which is the difference between the averages of the month and the extreme of the average mean daily temperatures, in order to obtain the absolute mean range of temperature; but this correction is quite small.

19. By reducing the mean temperature in the last columns of Tables I, II, and III to centigrade degrees, we get the second, third, and fourth columns in—

TABLE V.

θ	Temperature.				Residuals.
	January.	July.	Mean. Observed.	Mean. Computed.	
°	°	°	°	°	°
0	....	....	....	−17.0	....
10	−31.9	1.0	−15.5	15.8	+0.3
20	26.5	6.9	9.8	10.2	+0.4
30	16.9	13.8	− 1.6	− 2.2	+0.6
40	− 6.0	18.6	+ 6.3	+ 6.5	−0.2
50	+ 4.5	22.8	13.6	14.4	−0.8
60	12.9	26.6	19.8	20.4	−0.6
70	21.7	29.0	25.3	24.3	+1.0
80	25.9	28.4	27.2	26.4	+0.8
90	27.3	26.1	26.7	26.8	−0.1
100	27.9	24.0	25.9	26.0	−0.1
110	26.6	20.8	23.7	23.8	−0.1
120	23.0	15.6	19.3	20.2	−0.9
130	17.6	11.1	14.4	14.9	−0.5
140	11.1	6.4	8.8	8.2	+0.6
150	+ 3.6	0.0	+ 1.8	+ 0.9	+0.9
160	....	....	....	− 5.8	....
170	....	....	....	10.6	....
180	....	....	....	−12.4	....

If we put for the mean annual temperature—

(24) . . . . . $t = t_0 + a \cos\theta + b \cos 2\theta + c \cos 3\theta + d \cos 4\theta$

we get from this equation, with the fifteen observed values of t, and the corresponding values of θ in the first column, fifteen equations of condition for determining, by the method of least squares, the values of t_0, a, b, c, and d. With the values so determined, we get—

(25) . ∵ $t = 8^\circ.50 - 1^\circ.75 \cos\theta - 20^\circ.95 \cos 2\theta - 1^\circ.00 \cos 3\theta - 2^\circ.66 \cos 4\theta$

From this expression of t we get the computed values of t in the third column of the preceding table, which satisfies the observations with the residuals contained in the last column. Although this expression may represent the observations best for the latitudes for which they have been made, yet it cannot be regarded as representing the temperatures very accurately at or near the poles, especially the south pole.

20. In order to obtain the mean temperature of the earth's surface, we must integrate the expression obtained from (24) by multiplying it into sin θ and integrating with regard to θ, by which we get—

$$\int_\theta t \sin\theta = \int_\theta \sin\theta\left(t_0 + a\cos\theta + b\cos 2\theta + c\cos 3\theta + d\cos 4\theta\right)$$

$$= -\left(t_0 - \frac{1}{2}\right)\cos\theta - \frac{1}{4}\left(a - c\right)\cos 2\theta - \frac{1}{6}\left(b - d\right)\cos 3\theta - \frac{1}{8}c\cos 4\theta$$

$$- \frac{1}{10}d\cos 5\theta + C$$

in which—

$$C = \left(t_0 - \frac{1}{2}b\right) + \frac{1}{4}\left(a - c\right) + \frac{1}{6}\left(b - d\right) + \frac{1}{8}c + \frac{1}{10}d = t_0 + \frac{1}{4}a - \frac{1}{3}b - \frac{3}{8}c - \frac{1}{15}d$$

This integral gives for the northern hemisphere, using the values of t_0, a, b, c, and d in (25),—

$$\int_\theta t \sin \theta = t_0 + \frac{1}{2}a - \frac{1}{3}b - \frac{1}{2}c - \frac{1}{15}d = 15^\circ.30$$

and for the southern hemisphere,—

$$\int_\theta t \sin \theta = t_0 - \frac{1}{2}a - \frac{1}{3}b + \frac{1}{2}c - \frac{1}{15}d = 16^\circ.05$$

The mean of these two results gives 15°.67 for the mean temperature of the whole surface of the earth.

From Dove's Charts of Isothermal Lines, which do not extend beyond the middle latitudes in the southern hemisphere, it has been inferred that the southern hemisphere is colder than the northern, and this has been the accepted view ever since his charts were first published, in the year 1852; but, from the results obtained above, it is seen that the mean temperature of the southern hemisphere is the greater of the two. If, however, we compare the values of t in the preceding table for the two hemispheres between the parallels of 30° north and south, we find that the southern hemisphere is the colder of the two between these parallels; but beyond the parallels of about 35° the temperatures of the southern hemisphere become greater than those of the corresponding latitudes of the northern hemisphere, so that the average temperature is also greater, as shown above. The cause of this is found in the unequal distribution of land and water in the two hemispheres; for we now know, both from theory and observation, that there is a constant, though very slow, interchange of the water of the ocean between the equatorial and polar regions, which tends to diminish in some measure the difference of temperature between these regions, so that in the southern hemisphere, where there is mostly water, the temperatures of the higher latitudes must be greater than those of the same latitudes in the northern hemisphere, and the reverse for the lower latitudes. The small differences above between the mean temperatures of the two hemispheres is perhaps only of the order of the possible errors of these results, so that we cannot infer that there is any real difference in the averages of the two hemispheres.*

21. We now come to the subject of atmospheric pressure on the different parts of the earth's surface, upon which the values of $D_u P'$ and $D_v P'$ in the general equations of the preceding chapter depend. This pressure cannot be determined from theory, on account of the complexity of the equations and the uncertain element of friction entering into them, and we shall, therefore, endeavor to determine it, so far as possible, from observation. The very valuable and exhaustive paper by Buchan on this subject, the "Mean Pressure of the Atmosphere and the Prevailing Winds over the Globe, for the Month and for the Year," published in the year 1869,† left nothing undone which could have been done at the time in the way of determining the atmospheric pressure from observation on the different parts of the globe; but since that time there has been so great an accumulation of barometrical observations from almost all parts of the world, that it does not seem proper, in our present researches on the subject, not to avail ourselves of these observations, at least in some measure, in determining this pressure still more accurately for all places from which additional and more recent observations have been obtained. It is also thought that the knowledge which we now have of the relations between the barometric pressures and the velocities and directions of the winds, obtained from theory and corroborated by observation, can be now used in laying down isobaric lines for those countries and the vast expanse of ocean from which we have none, or at least only a very few, observations, much more accurately than has been done heretofore,

* See two papers on this subject by Dr. Hann in the "Zeitschrift der österreichischen Gesellschaft für Meteorologi'e," Band vii, S. 261, and Band xii, S. 100, which were not seen until after the preceding results were obtained, and in which these results are corroborated. If, however, the observations upon which the results obtained by Dr. Hann are based had been on hand at the time, the values of t in Table V would most probably have been diminished a very little in the extreme southern latitudes, and then the results obtained for the average temperatures of the two hemispheres might have been about equal.

† Transactions of the Royal Society of Edinburgh, vol. xxv.

since much may be inferred with regard to the barometric pressures from the known forces and directions of the winds. We shall, therefore, undertake to make out new charts of isobaric lines, not for each month, but simply for the mean annual pressures of the globe, and for the two extremes of January and July in the northern hemisphere, using for this purpose all the observations on hand, except in some parts of Europe, where there is so great an accumulation of them that all were not considered necessary for our purpose, since, in a general system of isobars for the whole globe, in which, from the scarcity of observations in many parts, there is much that is necessarily hypothetical and conjectural, it is not worth while to aim at extreme accuracy in certain comparatively very small parts of the surface of the globe. We shall also make out charts showing the annual variation of the atmospheric pressures over all parts of the globe, so far as this can be determined from observation, so that, with the mean annual pressure and the annual variation, the mean monthly pressures may be readily obtained, even with greater accuracy than they can be obtained from charts laid down from monthly averages, for it will be shown that all other neglected inequalities are generally either insensible, or at least smaller than the probable errors of monthly averages. These charts will be given on polar projections of the two hemispheres, since each hemisphere contains a complete system of winds and barometric pressures which are similar, and because in such projections there is less distortion of the parts in the higher latitudes, where, in the northern hemisphere, there are some features in the winds and barometric pressures, and their annual variations, which it is desirable to have more accurately represented than they can be in the usual projections.

22. For our purpose, we have put for each station for which we have observations of the pressure P—

$$(26) \quad \ldots \quad P = B_0 + B_1 \cos(\varphi - \varepsilon_1) + B_2 \cos(2\varphi - \varepsilon_2) + \&c.$$
$$= B_0 + M_1 \cos\varphi + N_1 \sin\varphi + M_2 \cos 2\varphi + N_2 \sin 2\varphi + \&c.$$

in which—

$$M_1 = B_1 \cos\varepsilon_1; \quad N_1 = B_1 \sin\varepsilon_1$$
$$M_2 = B_2 \cos\varepsilon_2; \quad N_2 = B_2 \sin\varepsilon_2$$
$$\tan\varepsilon_1 = \frac{N_1}{M_1}; \quad \tan\varepsilon_2 = \frac{N_2}{M_2}$$
$$B_1 = \frac{M_1}{\cos\varepsilon_1} \text{ or } \frac{N_1}{\sin\varepsilon_1}; \quad B_2 = \frac{M_2}{\cos\varepsilon_2} \text{ or } \frac{N_2}{\sin\varepsilon_2}$$

In the preceding expression of P—

B_0 = the mean annual barometric pressure;
B_1 = the coefficient of the annual inequality;
B_2 = that of the semi-annual inequality;
φ = an angle increasing in proportion to the time at a rate, on the average, of 30° per month;
ε_1 = a constant which is the value of φ at the time of the maximum of the annual inequality; and
ε_2 = a constant which is the value of 2φ at the time of the maximum of the semi-annual inequality.

If we put S_n for the monthly mean of the barometer for the nth month and the epoch of φ in the middle of December, we have, by regarding each month as the twelfth part of a year,—

$$B_0 = \frac{\Sigma_n S_n}{12}$$

$$6\,M_1 = \begin{pmatrix} S_1 - S_7 \\ S_{11} - S_5 \end{pmatrix} \cos 30° + \begin{pmatrix} S_2 - S_8 \\ S_{10} - S_4 \end{pmatrix} \cos 60° + \left(S_{12} - S_6 \right)$$

$$6\,N_1 = \begin{pmatrix} S_1 - S_7 \\ S_5 - S_{11} \end{pmatrix} \sin 30° + \begin{pmatrix} S_2 - S_8 \\ S_4 - S_{10} \end{pmatrix} \sin 60° + \left(S_3 - S_8 \right)$$

$$6\,M_2 = \begin{pmatrix} S_1 - S_4 \\ S_5 - S_8 \\ S_7 - S_{10} \\ S_{11} - S_2 \end{pmatrix} \cos 60° + \begin{pmatrix} S_{12} - S_3 \\ S_6 - S_9 \end{pmatrix}; \quad 6\,N_2 = \begin{pmatrix} S_1 - S_4 \\ S_2 - S_5 \\ S_7 - S_{10} \\ S_8 - S_{11} \end{pmatrix} \sin 60°$$

With the values of M_1, M_2, N_1, and N_2, given by these formulæ, we get from the preceding expressions the values of B_1, B_2, ε_1, and ε_2.

The preceding expression of P is simply a transformation of what is usually called Bessel's formula, in which sines are used, instead of the cosines in the form of expression here adopted. This form is preferable to the other, since from the values of ε_1 and ε_2 the times of the maxima of the inequalities are more readily obtained, and this is made still more convenient by having the constants ε_1 and ε_2 of the angles in the expression negative, as is usual in all tidal expressions of this sort, for in this case we have merely to add to the assumed epoch of the time-angles the time which is required for the angles to change by the quantity ε_1 or ε_2 in order to have the time of the maximum of the inequality. For the annual inequality, we divide ε_1, expressed in degrees, by 30, and for the semi-annual inequality ε_2 by 60, in order to get the time in months by which the maximum follows the assumed epoch of the middle of December.

The preceding formulæ for obtaining M_1, M_2, N_1, and N_2 follow directly from the determination of these quantities by the method of least squares in the special case of twelve equal divisions of the period of the principal inequality. The values, therefore, of the constants B_1, B_2, ε_1, and ε_2 thus obtained are the *most probable* values of these constants.

The form of (26) can likewise be applied to represent the temperature of the earth or atmosphere at any place, in which case the principal inequality has an annual period. In the case of both atmospheric pressure and temperature, more than two inequalities need not be considered; for if those of a lower order have sensible coefficients, they are of an order much smaller than the probable errors of the constants determined from observation, unless the period of observation embraces a very long series of years.

23. More convenient formulæ for the determination of the constants in (26) may be obtained upon the principle of averages, and the results obtained upon this principle, though differing a little from the most probable results given by the preceding formulæ, are sufficiently accurate in all meteorological researches, and the differences between the results of the two sets of formulæ will generally be found to be much less than the probable errors of the determinations.

If we put—

$a =$ the average of all the observations of P within the limits of $\varphi = \varphi_{,}$ and $\varphi = \varphi_{,,}$,

$\varphi' =$ the mean value of φ between the limits φ' and φ'',

by considering only the first two inequalities in P (26), and supposing the observation t equally distributed in time, we have—

$$a = B_0 + k\,B_1 \cos(\varphi' - \varepsilon_1) + k'\,B_2 \cos(2\,\varphi' - \varepsilon_2) \tag{27}$$

in which—

$$\left\{\begin{aligned} k &= \frac{2 \sin \frac{1}{2}(\varphi_{,,} - \varphi_{,})}{\varphi_{,,} - \varphi_{,}} = \frac{2 \sin \frac{1}{2} c}{2\,n\,\pi + c} \\ k' &= \frac{\sin(\varphi_{,,} - \varphi_{,})}{\varphi_{,,} - \varphi_{,}} = \frac{\sin c}{2\,n\,\pi + c} \end{aligned}\right. \tag{28}$$

c in the last form of expression of k and k' being the excess of $\varphi_{,,} - \varphi_{,}$ over an equal number of periods $2\,n\,\pi$ of the inequality.*

Where $\varphi_{,,} - \varphi_{,} = 2\,n\,\pi$, that is, where any number of even multiples of the period of the angle φ is used in taking the average, a, the arc c, and consequently k and k', vanish, and we have $a = B_0$. The same is sensibly true in the case of a long series of observations, since c, and consequently $2 \sin \frac{1}{2} c$ and $\sin c$, then becomes very small in comparison with $2\,n\,\pi$ in the denominator, in which n denotes the number of periods of the inequality used.

If we take the observations within the limits of the half-period $\varphi_{,,} - \varphi_{,} = \pi$, since $\sin \pi = 0$, we then have $k' = 0$, and (27) becomes—

$$a = B_0 + k\,B_1 \cos(\varphi' - \varepsilon_1)$$

* The preceding results of this section are demonstrated in my Tidal Researches, p. 158, published as an appendix to the United States Coast Survey Report for 1874.

The same is of course true if we take any number of successive half-periods within the same limits of φ. If we take the average for the other alternate half-periods, we get—

$$a = B_0 - k\,B_1 \cos(\varphi' - \varepsilon_1)$$

If we therefore reverse the signs of the observations for the latter, we get for the average—

$$(29) \quad \ldots\ldots\ldots\ldots \quad \begin{aligned} a &= k\,B_1 \cos(\varphi' - \varepsilon_1) \\ &= k\,M_1 \cos\varphi' + k\,N_1 \sin\varphi' \end{aligned}$$

If we put S_n = the monthly average of the nth month, and assume the epoch of the angle φ at the beginning of January, and take the limits $\varphi_{,}$ and $\varphi_{,,}$, so that $\varphi' = 0$, and put—

$$(30) \quad \ldots\ldots\ldots\ldots \quad \left\{ \begin{aligned} A &= S_1 + S_2 + S_3 \\ B &= S_4 + S_5 + S_6 \\ C &= S_7 + S_8 + S_9 \\ D &= S_{10} + S_{11} + S_{12} \end{aligned} \right.$$

we get from (29), since in this case $\cos\varphi' = 1$ and $\sin\varphi' = 0$,—

$$12\,a = 12\,k\,M_1 = S_{10} + S_{11} + S_{12} + S_1 + S_2 + S_3 - S_4 - S_5 - S_6 - S_7 - S_8 - S_9 = (A + D) - (B + C)$$

If we now assume the limits so that φ' falls on the 1st of April, we have in (29) $\sin\varphi' = 1$, and $\cos\varphi' = 0$, and we get—

$$12\,a = 12\,k\,N_1 = S_1 + S_2 + S_3 + S_4 + S_5 + S_6 - S_7 - S_8 - S_9 - S_{10} - S_{11} - S_{12} = (A + B) - (C + D)$$

With the value of $k = \frac{1}{\pi}$ from (28), since $\varphi_{,,} - \varphi_{,}$ in this case is equal to $\frac{1}{2}\pi$, these give—

$$(31) \quad \ldots\ldots\ldots\ldots \quad \left\{ \begin{aligned} M_1 &= 0.1309\,(A + D - B - C) \\ N_1 &= 0.1309\,(A + B - C - D) \end{aligned} \right.$$

With the values of M_1 and N_1, we obtain B_1 and ε_1 by the formulæ in § 22.

If we now take the averages for intervals of the angle, or $\varphi_{,,} - \varphi_{,}$ equal to $\frac{1}{2}\pi$, or 90°, changing the signs of the observations for each second alternating interval, it is readily seen that the first inequality in (27) is eliminated, since in this case (28) gives $k = 0$, and we get, instead of (29),—

$$(32) \quad \ldots\ldots\ldots\ldots \quad a = k'\,M_2 \cos 2\varphi' + k'\,N_2 \sin 2\varphi'$$

In this case, the half-period of the angle embraces only three months; and, in order to obtain the value of M_2, we must use intervals of two months only, so as to have φ' fall in the middle of the interval, and we thus get, since $\cos 2\varphi' = 1$ and $\sin 2\varphi' = 0$,—

$$8\,a = 8\,k'\,M_2 = S_{12} + S_1 - S_3 - S_4 + S_6 + S_7 - S_9 - S_{10}$$

In this case, we have the range between the limits $\varphi_{,,} - \varphi_1 = 60°$, and hence we get from (28),—

$$k' = \frac{\sin 60°}{\frac{1}{3}\pi} = 0.827$$

If we now take the limits of the alternate intervals $\varphi_{,}$ and $\varphi_{,,}$, so that φ' of the first falls on the middle of February, we shall have $\sin 2\varphi' = 1$ in (32) and $\cos 2\varphi' = 0$, and consequently—

$$12\,a = 12\,k'\,N_2 = S_1 + S_2 + S_3 - S_4 - S_5 - S_6 + S_7 + S_8 + S_9 - S_{10} - S_{11} - S_{12}$$

Since we have in this case $\varphi_{,,} - \varphi_{,} = 90°$, (28) gives—

$$k' = \frac{1}{\frac{1}{2}\pi} = \frac{2}{\pi}$$

We therefore get from the preceding expressions of $8\,k'\,M_2$ and $12\,k'\,N_2$, with the corresponding values of k' for each,—

$$(33) \quad . \quad . \quad . \quad \begin{cases} M_2 = 0.1511\,[(S_1 - S_3) + (S_6 - S_4) + (S_7 - S_9) + (S_{12} - S_{10})] \\ N_2 = 0.1309\,[(A + C) - (B + D)] \end{cases}$$

With the values of M_2 and N_2 given by (33), we get, by the formulæ in § 26, the values of B_2 and ε_2.

It is very convenient in practice to obtain by (31) and (33) the values of M_1, N_1, and M_2, N_2, from observation, and the values so found are very accurate when the expression of P (26) is so convergent as to make the inequalities after the first two very small or entirely insensible, as is the case in meteorology. In a comparison of the values of B_1 for thirty cases, obtained from series of meteorological observations by both of the methods which have been given, the average of the differences by the two methods, taken without regard to signs, was only 0.13^{mm}, the maximum being 0.39^{mm}, and in the case of the values of B_2 the differences were of the same order. Even in cases in which it is desirable to use the former more accurate formulæ of the preceding section, these latter will be found a very convenient check within very narrow limits.

Where the range of angle $\varphi_{,,} - \varphi_{,}$, belonging to a group of observations of which the average a is taken, is small, the values of k and k' (28) do not differ sensibly from unity, and, by comparing (26) with (27), it is seen that the average can be used as the value of the function belonging to the middle of the interval, in which the value of φ is φ'. If, however, the range should be considerable, this average must be corrected in order to obtain the value of the function for the middle of the group of observations. From (26) and (27) we get—

$$(34) \quad . \quad . \quad . \quad P = a + (1 - k)\,B_1 \cos(\varphi' - \varepsilon_1) + (1 - k')\,B_2 \cos(2\,\varphi' - \varepsilon_2)$$

The last two terms, therefore, will be small corrections to the average a in order to get the value of the function P for the middle of the group, for which $\varphi = \varphi'$. For instance, if we had monthly averages, we should have $\varphi_{,,} - \varphi_{,} = 30^\circ$, and (28) would give $1 - k = 1 - 0.9886 = 0.0114$, and $1 - k' = 1 - 0.9549 = 0.0451$, and the correction is—

$$P - a = 0.0114\,B_1 \cos(\varphi - \varepsilon_1) + 0.0451\,B_2 \cos(2\,\varphi' - \varepsilon_2)$$

The last term, on account of the smallness of B_2, is generally very small in monthly averages. When the range $\varphi_{,,} - \varphi_{,}$ is larger, of course these corrections become of more importance.

24. The constants in the last columns of the following table have been deduced, by means of the preceding formulæ, from the monthly means reduced to sea-level and the gravity of the parallel of 45°, contained in Rikatcheff's paper entitled "La Distribution de la Pression Atmosphérique dans la Russie d'Europe," published in the Repertorium für Meteorologie, Band iv, Heft 1, S. 46, 47.

TABLE VI.

Place.	Latitude.		Longitude.		Altitude.	Years of observation.	B_0.	B_1.	B_2.	ϵ_1.	ϵ_2.
	°	'	°	'	m.		mm.	mm.	mm.	°	°
Kem	64	57	34	39	13.7	7	757.3	1.7	1.1	123	22
Archangel	64	33	40	32	10.7	19	757.5	0.7	0.5	151	219
Helsingfors	60	10	24	57	11.6	15	759.6	0.5	0.5	86	192
St. Petersburg	59	56	30	16	4.5	50	759.9	0.6	0.5	35	197
Boyolovsk	59	45	60	1	193.7?	16	761.6	3.6	0.5	19	187
Reval	59	26	24	45	(?)	17	759.7	0.3	1.3	143	248
Port Baltic	59	21	24	3	8.5	33	759.8	0.2	0.5	145	260
Dorpat	58	23	26	43	68.3 & 43.0?	22	760.3	0.2	0.3	225	180
Nijne Taguilsk	57	56	60	5	189.4?	26	762.3	4.4	1.7	11	152
Kostroma	57	47	40	55	106.2?	21	761.4	2.3	1.0	11	185
Riga	56	58	24	6	16.6?	21	760.5	0.5	0.4	6	236
Catherineburg	56	49	60	35	283.8	31	762.8	4.5	0.9	14	190
Mitau	56	39	23	44	4.9	19	760.5	0.8	0.6	354	206
Kazan	55	47	49	8	71.1	17	762.4	4.2	1.1	20	193
Moscow	55	46	37	40	145.1	48	762.3	2.3	0.8	359	162
Slatovsk	55	10	59	40	415.4?	33	763.0	5.4	0.2	10	21
Kalouga	54	30	36	15	162.6?	13	762.3	2.7	0.8	354	221
Orel	52	57	36	5	165.2?	8	762.3	2.9	1.4	349	190
Tambow	52	44	41	28	165.5?	14	762.9	3.2	0.3	12	212
Warsaw	52	13	21	2	119.4	35	761.3	1.4	0.2	346	106
Orenburg	51	46	55	6	103.5	28	763.8	5.9	0.7	8	182
Koursk	51	45	36	8	209.4?	25	762.6	2.8	0.7	350	189
Ouralsk Fortress	48	37	61	16	108.9?	8	762.9	7.6	1.6	6	192
Lougan	48	35	39	20	62.0?	31	762.9	4.0	0.5	0	226
Nikolaief	46	58	31	58	55.0 & 19.0	26	762.4	3.1	0.1	356	259
Odessa	46	29	30	44	53.3 & 65.3	18	762.4	2.9	0.3	352	248
Astrakhan	46	21	48	2	....	12	763.0	4.6	0.5	2	304
Stavropol	45	3	41	59	555.7	27	762.3	4.4	0.5	10	345
Tiflis	41	43	44	47	459.9 & 409.3	26	763.2	4.0	0.9	0	310
Bakou	40	22	49	50	−16.0	18	761.6	4.4	0.8	2	266
Hammerfest	70	40	23	46	6.4	13	756.4	3.9	1.1	177	262
Happaranda	65	51	24	11	11.6	12	758.5	1.0	0.5	126	224
Stykisholm	65	4	−22	43	11.3	23	754.0	4.5	2.0	174	222
Reykjavik	64	40	−22	0	11.0	17	752.7	5.3	0.7	167	283
Christian Sound	63	7	7	45	19.8	8	756.7	2.9	1.3	168	253
Heernösand	62	38	17	57	19.2	12	758.7	2.6	0.9	135	272
Christiania	59	55	10	41	22.7	35	759.0	0.5	0.6	105	220
Upsala	59	52	17	38	24.0	18	758.3	0.3	0.5	124	278
Copenhagen	55	41	12	35	3.6	11	760.5	0.4	1.0	238	284
Stralsound	54	29	12	20	14.9	22	761.0	0.7	0.4	324	267
Stettin	53	35	14	34	21.8	16	761.2	0.7	0.3	297	11
Götersloh	51	54	8	23	81.2	22	761.2	0.3	0.4	243	54
Dublin	53	22	− 6	21	49.8	33	760.3	1.2	0.3	170	354
Berlin	52	30	13	23	46.8	32	761.9	0.3	0.3	305	59
Utrecht	52	5	5	7	13.4	20	761.9	0.3	0.5	241	3
London	51	28	0	0	0.0	......	761.2	0.7	0.5	155	57
Breslau	51	7	17	2	147.5	39	762.7	1.7	0.5	342	25
Brussels	50	51	4	22	56.7	35	761.6	0.4	0.7	262	0
Prague	50	5	14	23	201.2	19	762.3	1.6	0.8	335	17
Cracow	50	4	19	57	215.7	12	762.3	1.7	0.4	326	58
Breszew	50	3	22	0	213.7	11	762.4	1.7	0.1	328	148
Paris	48	50	2	20	65.8	15	762.4	0.3	1.1	4	26
Vienna	46	55	16	20	191.3	17	762.1	1.7	0.8	335	36
Triest	45	39	13	44	....	......	761.1	0.9	0.5	341	47
Bordeaux	44	50	− 0	35	22.9	10	763.1	0.8	0.8	297	48
Orange	44	8	4	48	45.4	36	762.1	0.9	0.5	311	36
Toulouse	43	37	− 1	28	198.1	22	763.2	1.0	1.1	338	40
Constantinople	41	0	28	59	(?)	28	763.0	2.6	0.6	355	15
Naples	40	52	14	15	146.9	11	763.9	0.8	1.5	269	27

TABLE VI—Continued.

Place.	Latitude.	Longitude.	Altitude.	Years of observation.	B_0.	B_1.	B_2.	ϵ_1.	ϵ_2.
	° ′	° ′	m.		mm.	mm.	mm.	°	°
Lisbon	38 43	− 9 8	135.4	11	760.8	0.8	0.4	7	245
Athens	37 58	23 43	80.5	11	760.3	1.8	0.6	356	247
Alger	36 43	3 3	20.1	13	763.0	1.1	1.2	347	24
Oran	35 40	− 0 38	50.0	3	763.2	1.8	0.9	15	8

25. The results contained in the following table have been deduced in the same manner as those of the preceding table from the monthly means of observations given from time to time in the "Zeitschrift der österreichischen Gesellschaft für Meteorologie." These observations have been, in most cases, collected, revised, and discussed, and, in many cases, corrected, by Dr. Hann, who has spent much time and labor upon them, and to whom, therefore, much credit is due, and the references in the following table are to the "Zeitschrift für Meteorologie" alone, where references will be found to the original sources from which the observations have been obtained, and due credit given. These observations include many of those used by Buchan, and also most of the observations made in all parts of the world since the publication of Buchan's paper, already referred to. These observations as given were not reduced to sea-level, nor to the gravity of the parallel of 45°. For the former reductions, we have used mostly the table on page 91 of Guyot's Hypsometrical Tables; but for all places of considerable altitude, the reductions have been made by the following formula:—

$$(35) \quad . \; . \; . \; . \; . \quad \log P' - \log P = \frac{h}{18428\,(1 + 0.004\,t + 0.00001\,h)}$$

in which the coefficient of the temperature t is taken so as to include approximately the effect of moisture, and in which the temperature is supposed to decrease $0^\circ.5$ for each 100 meters of altitude. The altitude h in the formula must be expressed in meters.

In a few cases, the altitudes were not given, and, where given, there was some uncertainty with regard to the manner in which they may have been obtained. If obtained barometrically, as is sometimes the case with altitudes thus given, then the reduced pressures to sea-level are simply the assumed pressures at sea level used in determining the altitudes, and hence are worthless. In drawing isobars on the charts, however, those results obtained from observations at considerable altitudes, in which there was considerable uncertainty in the reductions, were not allowed much, if any, weight.

Instead of reducing the monthly means to sea-level, this reduction was applied merely to the mean of the barometric pressures B_0 given in the following table, using the mean temperature. This leaves an inequality in the reduction to sea-level, depending upon the annual inequality of temperature, uncorrected, which requires a correction to be applied to the coefficient B_1. The formula for this correction, as deduced from (35), is—

$$(36) \quad . \; . \; . \; . \; . \; . \quad \Delta_t P = \Delta B_1 = \frac{h}{18428} \times 0.004\;\Delta t \times \frac{P}{0.4343} = \frac{Ph\,\Delta t}{2001280}$$

in which Δt is the variation of the extreme of the mean monthly temperatures in January or July from the mean temperature, and in which the value of P at the height of $\frac{1}{2}h$ should be used when h is great. The corrections given by this formula under the head ΔB_1 in the following table must be applied to B_1, in order to have the coefficient of annual inequality at the sea-level.

Table VII.

Place.	Latitude.		Longitude.		Altitude.	Years of observation.	Authority: Zeitschrift für Meteorologie. B.	S.	B_0.	B_1.	B_2.	ϵ_1.	ϵ_2.	Reduced to sea-level and gravity of the parallel of 45°. B_0.	ΔB_1.
	°	'	°	'	m.				mm.	mm.	mm.	°	°	mm.	mm.
Port of France	−22	30	166	39	7	.....	4	460	762.8	2.5	0.3	196	188	761.4	....
Jerusalem	31	47	37		762	3.5	4	166	695.6	1.9	0.8	21	330	759.0	2.2
Tahiti	−17	32	−149	34	0	5	4	528	759.7	1.5	0.3	233	208	758.1	....
Adelaide	−34	57	138	38	0?	7	5	121	759.5	2.6	0.5	104	215	758.8?	....
Hobarttown	−42	52	147	27	32	20	5	121	756.1	1.6	0.6	134	194	758.9	0.1
Melbourne	−34	49	144	58	37	10	5	99	759.4	2.5	0.3	113	195	762.2	0.2
Calcutta	22	33	88	21	6	16	5	247	756.4	6.5	0.8	6	288	755.9	....
Capstadt	−33	56	18	27	0	20	5	428	762.9	2.8	0.2	205	48	762.1	....
Höhenpeisenburg	47	48	....		914	13	5	509	676.9	1.9	0.7	228	52	761.6	3.3
Natal	−29	36	30	2	638.5	8	5	375	708.3	2.7	0.2	186	352	761.0	0.8
Mauritius	−20	10	57	29	9	7	5	552	763.4	4.1	0.4	211	278	762.7	....
Brisbane	−27	28	153	6	44	2.5	5	505	762.1	3.0	0.4	193	160	764.5	0.1
Puerto Monti	−41	30	−72	52	10	1.5	5	399	761.6	0.6	1.6	274	240	762.2	....
Santiago	−33	26	−70	37	569	6.5	5	441	717.1	1.4	0.3	211	198	766.1	1.3
Port Said	31	18	32	18	3	3	5	228	760.7	3.5	0.7	15	232	760.0	....
Ismailia	30	38	32	13	7.6	3	5	228	760.0	3.8	0.8	17	287	759.7	....
Suez	29	57	32	32	6	3	5	228	760.9	3.8	0.7	11	291	760.5	....
San Francisco	37	48	122	23	0	9	5	642	763.7	2.4	0.1	25	327	763.2	....
Sacramento	38	35	121	28	25	9	5	642	761.5	3.1	0.3	24	331	762.5	....
Palermo	38	7	13	21	70.3	78	5	614	754.6	0.5	0.4	266	9	760.3	0.2
Sereno	−29	55	71	17	18	2	6	26	760.3	2.0	0.6	215	221	760.9	....
New Westminster	49	13	122	53	16.5	2	6	76	762.0	0.5	1.2	95	104	763.8	....
Marietta	39	25	81	29	177	40	6	79	743.8	0.9	0.3	275	56	759.2	0.8
Sydney	−33	52	151	11	47	11	6	84	762.7	2.9	0.6	164	173	765.9	0.1
Mendoza	−32	51	67	32	8	10	6	138	760.6	1.8	0.6	191	141	760.5	....
St. Martins	45	32	−73	36	36	10	6	145	756.3	1.6	0.8	289	350	759.6	0.2
Lima	−12	3	−79	29	152	1	6	176	747.1	2.2	0.4	249	224	758.4	0.3
Rio Janeiro	−22	54	−43	20	64	6	6	184	757.4	3.0	1.0	187	16	761.6	0.1
Krasnojarsk	56	0	92	50	(?)	10	6	223	758.1	6.9	0.8	1	178	....	....
Osaka	34	20	135	10	(?)	1	6	251	761.1	4.1	0.9	5	220	....	....
Scutari	41	0	29	3	18.3	5	6	298	760.3	2.1	0.9	12	220	761.7	....
Terceira	38	36	−27	15	53.8	6	6	310	761.0	1.9	0.9	201	64	765.3	0.1
St. Miguel	37	44	−26	55	20	6	6	310	764.5	2.1	0.6	206	79	765.8	....
Taschkent	41	19	69	16	(?)	1	6	329	763.2	3.7	1.7	54	222	....	....
Auckland	−36	50	174	51	0	12	6	370	761.5	1.2	0.8	92	181	760.9	....
Taranaka	−39	4	174	5	0	6	6	370	759.9	1.9	0.5	102	185	759.4	....
Nelson	−41	16	173	19	0	6	6	370	759.6	2.1	0.9	142	56	759.3	....
Southland	−46	18	168	10	0	11	6	370	757.1	2.4	0.3	121	84	757.1	....
Somerset	−10	44	142	16	21.3	3	6	378	758.3	1.6	0.3	222	128	758.4	....
Fort No. 1, Syr Daria	45	45	64	27	(?)	3	6	384	758.1	6.1	0.2	8	215	....	....
Phare de Douai	50	50	146	47	(?)	2	6	384	747.5	1.7	0.5	352	85	....	
Praia	14	13	−23	30	35	1.5	6	384	758.8	0.3	0.6	110	298	760.3	....
Horta Fayall	38		−28		20	2	6	411	762.0	0.7	2.7	178	58	763.4	....
Newchwang	40	57	121	27	0	1	7	7	765.5	7.4	1.2	4	143	765.3	....
Ancud	−41	51	−74		15	2	7	11	757.1	1.6	0.8	317	114	758.2	....
Bangkok	13	43	100	25	(?)	4	7	23	759.5	2.9	0.3	17	55	....	....
Saigun	10	48	106	40	(?)	1	7	23	760.8	1.2	0.5	20	359	....	....
Decima	32	14	129	42	8	2	7	47	761.3	5.7	0.6	10	240	761.4	....
Nafa	26	13	128	44	10	2	7	47	760.4	5.1	0.9	21	289	760.0	....
Freemantle	−32	4	115	45	0	3	7	55	762.7	2.0	1.0	180	243	761.8	....
Cairo	29	59	31	18	28.5	5	7	67	759.1	3.6	0.6	9	235	760.7	....
Alexandria	31	11	29	53	23	3	7	140	760.0	3.6	0.7	7	217	761.1	0.4
Mannheim	49	20	8	27	116	12	7	144	753.5	0.8	1.1	310	42	764.3	....
Belize	17	30	−88	18	(?)	4	7	160	761.7	1.2	0.8	1	31	760.1	....
Strasburg	48	34	7	45	39	39	7	238	749.5	0.3	0.7	324	43	762.8	0.5
East Falkland	−51	41	−57	42	0	9	7	254	750.3	0.8	1.1	202	196	750.8	....
Valparaiso	−33	2	−71	40	0	......	7	254	763.9	1.6	1.0	218	218	763.1	....

TABLE VII—Continued.

Place.	Latitude.	Longitude.	Altitude.	Years of observation.	Authority: Zeitschrift für Meteorologie. B.	S.	B_0.	B_1.	B_2.	ε_1.	ε_2.	Reduced to sea-level and gravity of the parallel of 45°. B_0.	ΔB_1.
	° ′	° ′	m.				mm.	mm.	mm.	°	°	mm.	mm.
Arva Varalgo	49 15	37 15	490	20	7	300	717. 5	0. 8	0. 4	270	24	761. 8	2. 1
Gratz	47 4	15 28	371	31	7	316	730. 8	1. 1	0. 8	299	25	764. 2	1. 8
St. Louis	38 37	— 90 16	154	14	7	326	749. 9	1. 7	0. 7	336	65	763. 3	0. 8
Yokohama	35 27	139 40	0	2	7	361	760. 6	3. 2	1. 5	4	230	759. 5	....
Caraccas	10 38	66 55	927	3	7	380	684. 5	0. 5	0. 5	128	224	758. 9	0. 3
Datschitz	49 5	15 26	465	8	7	381	720. 5	1. 3	0. 5	216	350	762. 5	1. 9
Batavia	— 6 11	106 50	8	3	7	399	759. 0	0. 2	0. 1	296	123	757. 7	....
Magador	31 30	9 45	16. 6	4	8	8	762. 2	1. 2	0. 5	21	359	762. 8	....
Nice	43 41	7 6	0	16	8	13	760. 8	0. 2	0. 6	293	20	760. 7	....
Schafburg	47 46	13 26	1767	1. 5	8	29	614. 0	3. 8	1. 1	216	77	760. 3	2. 3
Fernanda Po	3 46	8 36	30	4. 5	8	47	757. 3	0. 5	0. 2	233	59	757. 0	....
Lakainalulu	20 52	— 156 40	199	1	8	70	747. 0	1. 1	0. 5	91	350	762. 6	0. 1
Honolulu	21 16	— 157 52	0	1	8	71	764. 1	0. 6	0. 6	196	307	762. 6	....
Victoria	22 16	114 10	0	8	8	72	760. 7	6. 1	0. 6	15	285	759. 3	....
Simla	31 6	77 11	2282	3	8	91	589. 1	2. 0	1. 2	351	220	....	....
San Antonio	29 32	— 98 24	172	1	8	91	755. 6	3. 5	1. 1	38	342	769. 7	0. 7
Smyrna	38 26	27 10	0	9	8	123	759. 1	2. 4	1. 1	6	262	759. 3	....
Madrid	40 24	— 3 42	655	11	8	188	06. 9	0. 6	0. 8	294	16	763. 4	2. 4
Providence	41 50	— 71 23	0	28½	8	208	760. 7	0. 9	0. 3	313	185	760. 5	....
Canton	23 8	113 17	12	10	8	219	762. 1	6. 1	1. 0	13	325	761. 8	....
Victoria Peak	22 17	114 10	532	2. 7	8	219	717. 7	3. 5	0. 5	14	301	761. 7	1. 1
Manáos	— 3 8	— 60 0	37	1	8	269	757. 6	1. 2	0. 3	148	90	758. 9	....
Havanna	23 8	— 82 28	19. 3	14	8	270	761. 3	1. 1	1. 3	32	29	761. 8	....
Vienna	48 12	36 22	195	90	8	281	744. 9	1. 0	0. 3	326	60	762. 7	0. 7
Gorée (Cape Verde)	14 40	— 17 26	6	4	8	301	757. 7	0. 6	0. 5	49	19	756. 5	....
Manilla	14 36	128 21	33	5	8	334*	755. 0	2. 2	0. 5	32	333	756. 3	....
Murcia	37 59	— 1 7	43	9	9	8	759. 7	1. 0	1. 0	2	14	763. 1	....
St. George d'Elmira	5 5	— 1 20	18	3	9	44	759. 4	1. 6	0. 6	220	49	759. 1	....
Christiansburg	5 36	— 0 10	20	15	9	45	759. 1	1. 5	0. 8	216	33	758. 9	....
Arica (Peru)	— 18 25	— 70 22	0	1	9	60	761. 8	1. 3	0. 2	222	255	760. 2	....
Cairo	29 57	31 18	37. 8	4	9	61	758. 1	3. 5	0. 9	11	284	760. 5	....
Gibraltar	36 6	— 5 21	15	14	9	77	763. 4	1. 0	0. 8	6	8	764. 1	....
San Fernando	36 28	— 6 12	29	16	9	77	761. 7	1. 0	0. 8	1	19	763. 7	....
Santiago	42 53	— 8 30	273	13	9	111	739. 4	0. 1	1. 2	85	34	763. 5	0. 6
Oviedo	43 23	— 5 52	236. 5	18	9	111	742. 7	0. 6	1. 0	233	51	763. 7	0. 6
Leipzic	51 20	12 33	118	40	9	128	751. 4	0. 5	0. 5	257	33	762. 6	0. 4
Bermuda	32 23	— 64 40	0	12	9	123	763. 9	0. 3	1. 4	193	32	763. 1	....
Innsbruck	47 16	11 24	574	40	9	185	707. 4	0. 6	0. 4	256	69	758. 3	2. 3
Vancouver Island	45°–50°	-120° - -125°	0	3	9	187	762. 4	0. 2	0. 8	260	313	762. 6	....
Zaragona	41 39	— 1 0	184	9	9	218	743. 5	0. 9	1. 3	5	25	759. 6	0. 6
Valadolid	41 39	— 4 47	760	9	9	218	702. 2	0. 3	1. 0	225	39	768. 2	2. 7
Vera Cruz	19 12	— 96 9	8	4	9	238	761. 8	2. 0	0. 8	339	40	761. 0	....
Bodenbach	59 43	14 12	142	46	......	......	749. 4	0. 9	0. 7	322	16	762. 7	0. 6
Binfield (Barbadoes)	13 4	— 59 37	336. 5	21	9	320	736. 3	0. 4	0. 2	108	60	763. 2	0. 1
Benares	25 20	82 0	80	10	......	......	750. 4	8. 1	0. 3	31	237	756. 0	0. 2
Rurki	29 52	77 56	268	9	......	......	734. 0	6. 8	0. 6	2	234	755. 7	0. 7
Alessandria	44 54	8 37	98	17	......	......	752. 6	0. 7	0. 7	352	66	761. 5	0. 5
Pola	44 52	13 51	31. 7	10	10	28	758. 7	0. 4	0. 4	256	354	761. 5	0. 1
Ancona	43 38	13 31	0	10	10	28	761. 8	0. 1	0. 4	217	20	761. 7	....
Nagasaki	31 44	129 42	37	10	10	96	762. 6	6. 3	1. 0	20	275	765. 1	....
Capiapo	27 25	— 70 23	395	4	10	111†	728. 2	1. 2	0. 3	210	230	761. 5	0. 7
Buenos Aires	—34 37	— 58 21	31	4	10	118	761. 8	3. 0	1. 1	188	177	763. 9	....
Alexandria	31 12	29 54	19	2	10	132	756. 4	2. 7	0. 8	18	96	757. 2	....
Gandokoro	4 55	31 28	465	1	10	192	721. 3	1. 3	0. 9	217	330	758. 1	0. 5
Chartum	15 36	32 36	388	1	10	192	724. 6	1. 3	0. 3	12	355	755. 1	1. 0

* Including previous one year, B. v, S. 67. † Including the previous two years, B. vi, S. 28.

TABLE VII—Continued.

Place.	Latitude.	Longitude.	Altitude.	Years of observation.	Authority: Zeitschrift für Meteorologie. B.	S.	B_0.	B_1.	B_2.	ε_1.	ε_2.	Reduced to sea-level and gravity of the parallel of 45°. B_0.	ΔB_1.
	° ′	° ′	m.				mm.	mm.	mm.	°	°	mm.	mm.
Chur	46 51	9 31	603	15	10	195	709.9	1.4	1.0	243	90	763.5	2.2
Eger	50 5	....	455	11	10	338	720.8	1.1	0.7	214	27	761.6	1.8
St. Louis	16 1	— 18 31	5	1	10	381	759.3	2.4	0.7	60	357	758.0	....
Port Blair	11 41	92 42	18.6	7	11	28	756.7	2.0	0.3	11	122	756.6	....
Hanan	50 8	8 55	102	6	11	29	754.1	1.0	0.8	262	9	763.7	....
Toronto	43 39	— 79 23	104	31	11	32	752.3	0.8	0.4	311	117	761.5	....
Superior City	45 40	— 92 8	197	10	11	58	744.3	0.8	0.5	0	100	762.6	....
Marquette	46 36	— 87 36	207	10	11	58	743.4	0.4	0.5	288	156	762.7	....
Detroit	42 21	— 83 7	180	10	11	58	746.1	1.2	0.6	306	103	762.4	....
Charlotte	43	....	87	10	11	58	754.4	0.9	0.4	328	126	762.4	....
Sau José de Costa Rica	9 56	— 84 0	1145	8	11	107	668.9	0.1	0.1	90	101	760.5	0.3
Spitzbergen	79 53	....	12	1	11	123	758.2	3.3	2.3	185	262	761.2	....
Sabine Island	74 32	16 4	0?	1	11	123	758.9	2.2	1.5	74	130	760.6	....
St. Martins de Hinx	43 47	....	40?	10	11	125	760.3	0.3	0.7	270	43	763.8	....
Mexico	19 25	....	2278	2	11	185	787.0	0.3	0.6	285	67	760.5	2.6
Porto	41 8	— 8 37	85	9	11	202	754.7	0.4	1.1	317	16	762.0	1.8
Guerdo	40 32	— 7 16	1039	9	11	202	675.3	1.3	1.1	219	20	763.5	3.2
Campo Major	39 1	— 7 5	288	9	11	202	737.7	0.8	1.0	345	10	762.6	0.9
Lagro	37 7	— 8 25	12	7	11	202	762.5	1.1	0.9	7	12	763.0	....
Angra	38 36	— 27 15	54	8	11	202	761.0	0.7	1.8	121	70	765.4	0.1
P. Delgado	37 40	— 25 55	20	7	11	202	764.5	1.6	0.9	209	38	765.8	....
Funchal	32 38	— 16 55	25	8	11	202	763.0	0.2	1.0	32	20	764.4	....
Hokitika	42 42	172 39	0	9.5	11	223	760.3	1.2	1.4	61	160	760.1	....
Christ Church	43 32	170 59	0	11.5	11	223	759.1	2.0	1.1	115	174	759.0	....
Corfu	39 38	19 53	0	11	11	283	761.6	1.0	0.3	239	235	761.2	....
Nicolajesk	63 8	140 43	0	11	11	283	756.7	2.8	1.4	20	150	757.2	....
Atlantic Ocean	48 0	....	From 2 to 3 meters.	......	10	158	760.6	1.4	1.5	196	0	761.0	....
	43 0	....		......	10	158	762.3	1.6	1.5	191	52	762.4	....
	38 0	....		......	10	158	763.8	2.0	1.8	176	39	763.6	....
	33 0	....		......	10	158	765.1	1.4	1.3	167	36	764.6	....
	28 0	....		......	10	158	765.2	1.0	1.6	125	40	764.4	....
	23 0	....		......	10	158	764.2	0.1	1.9	130	30	763.0	....
	18 0	....		......	10	158	762.6	0.2	0.3	79	351	761.3	....
	13 0	....		......	10	158	761.3	0.7	0.3	87	20	759.7	....
	8 0	....		......	10	158	760.4	0.4	0.3	183	64	758.7	....
	3 0	....		......	10	158	760.2	1.1	0.3	218	66	758.5	....
	0	....		......	10	158	760.3	1.4	0.5	223	71	758.6	....
	— 3 0	....		......	10	158	760.6	1.4	0.3	225	59	758.9	....
	— 8 0	....		......	10	158	761.4	1.4	0.3	230	53	759.7	....
	— 13 0	....		......	10	158	762.5	1.7	0.8	231	358	761.0	....
	— 18 0	....		......	10	158	763.6	1.9	0.8	221	16	762.2	....
	— 23 0	....		......	10	158	764.3	1.9	0.8	213	43	763.2	....
	— 28 0	....		......	10	158	764.3	2.1	0.3	214	236	763.5	....
	— 33 0	....		......	10	158	763.4	1.4	0.2	236	128	762.9	....
	— 38 0	....		......	10	158	762.2	0.5	0.2	238	198	762.0	....
	— 43 0	....		......	10	158	757.5	1.1	0.9	263	172	757.6	....
Atlantic Ocean	10 to 8 N.	20 to 30 W.	0	......	11	193	761.2	1.0	0.5	162	2	759.3	....
	8 to 6 N.	20 to 30 W.	0	......	11	193	760.8	0.6	0.1	170	41	758.9	....
	6 to 4 N.	20 to 30 W.	0	......	11	193	760.6	0.8	0.2	212	90	758.6	....
	4 to 2 N.	20 to 30 W.	0	......	11	193	760.9	1.4	0.5	212	50	758.9	....
	2 to 0	20 to 30 W.	0	......	11	193	760.9	1.6	0.7	219	52	758.9	....

TABLE VII—Continued.

Place.	Latitude.		Longitude.	Altitude.	Years of observation.	Authority: Zeitschrift für Meteorologie. B.	S.	B_0.	B_1.	B_2.	ε_1.	ε_2.	Reduced to sea-level and gravity of the parallel of 45°. B_0.	ΔB_1.
	°	'	° '	m.				mm.	mm.	mm.	°	°	mm.	mm.
Around the Cape of Good Hope*	— 31	0	0 to 20 E.	0	......	9	255	764.4	2.2	......	225	......	763.4	....
	— 33	0	0 to 20 E.	0	......	9	255	763.3	2.7	......	247	......	762.5	....
	— 35	0	13 to 35 E.	0	......	9	255	761.8	2.0	......	242	......	761.1	....
	— 37	0	13 to 35 E.	0	......	9	255	761.0	1.4	......	255	......	760.5	....
	— 39	0	13 to 35 E.	0	......	9	255	761.4	0.8	......	249	......	761.0	....
	— 41	0	13 to 35 E.	0	......	9	255	760.1	1.2	......	266	......	759.9	....
	— 43	0	13 to 35 E.	0	......	9	255	758.3	1.3	......	236	......	758.2	....
	— 45	0	13 to 35 E.	0	......	9	255	756.4	2.0	......	232	......	756.4	....
	— 46	30	13 to 35 E.	0	......	9	255	754.1	1.7	......	285	......	754.3	....

* Deduced from the average of about 1,000 observations each.

26. The results in the following table are deduced from the monthly means contained in Buchan's paper on the Mean Pressure of the Atmosphere and the Prevailing Winds on the Globe,* for places not contained in the preceding tables.

TABLE VIII.

Place.	Latitude.		Longitude.		Altitude.	Years of observation.	B_0.	B_1.	B_2.	ε_1.	ε_2.	For sea-level and gravity of the parallel of 45°. B_0.	ΔB_1.
	°	'	°	'	m.		mm.	mm.	mm.	°	°	°	mm.
Armagh, Ireland	54	21	— 6	49	64	11	752.7	1.4	0.9	191	312	759.1	0.2
Belfast, Ireland	54	36	— 5	56	0	11	759.0	1.3	1.0	174	315	759.6	......
Cork, Ireland	51	53	— 8	28	8	11	759.5	1.4	1.0	190	347	760.7	.....
Aberdeen, Scotland	57	9	— 2	7	34	11	754.9	1.8	1.4	170	292	752.8	......
Glasgow, Scotland	55	3	— 4	18	55	11	752.6	1.5	1.3	179	296	758.3	0.1
Milne-Graden, Scotland	55	0	— 2	12	31	11	755.9	1.6	1.3	173	298	759.4	......
Liverpool, England	53	25	— 2	59	0	11	759.2	1.2	1.3	178	326	759.7	.....
Norwich, England	52	38	1	18	0	11	760.5	0.6	1.5	198	321	761.0	......
Helston, England	50	7	— 5	16	32	20	759.0	0.6	0.7	163	49	762.2	......
Geneva, Switzerland	46	12	6	9	407	25	726.4	1.1	1.1	273	36	....	1.4
Turin, Italy	45	4	7	41	279	74	739.1	1.7	0.6	214	56	764.0	1.0
Rome, Italy	41	54	12	28	0	15	761.7	0.2	1.8	301	58	761.5	......
Malta, Italy	35	54	14	31	0	6	762.5	0.3	0.2	276	68	761.9	......
Bologna, Italy	44	30	11	21	74	40	755.1	0.6	0.6	350	323	761.8	0.3
Krakau, Austria	50	4	19	55	216	19	742.5	1.3	0.6	290	336	762.5	0.8
Kremsmünster, Austria	48	3	14	6	283	19	728.0	1.1	0.9	285	20	762.4	1.2
Szegedin, Austria	46	15	20	6	84	12	754.0	2.0	0.2	324	312	761.8	0.3
Tesina, Austria	43	11	16	25	19	9	759.1	0.5	0.3	300	0	760.6	......
Munich, Bavaria	48	9	11	34	511	10	716.0	1.2	1.1	254	2	761.3	1.6
Königsberg, Prussia	54	43	20	29	22	10	758.5	0.1	1.0	225	239	761.2	......
Dantsic, Prussia	54	21	18	41	9	32	760.3	0.4	0.2	45	148	761.7	......
Corfu, Greece	39	39	19	55	0	6	761.8	1.2	0.4	331	217	761.5	......
Barnaul, Russia	53	20	83	57	122	19	749.3	8.1	1.5	15	183	761.2	0.8
Jakutsk, Russia	62	2	129	14	87	1½	753.8	7.2	0.3	0	120	763.3	0.9
Bógolovsk, Russia	59	45	60	2	181	26	741.4	3.2	1.0	1	181	759.4	1.2
Ayansk, Russia	56	27	138	26	(?)	2	756.3	2.0	2.0	33	168	....	......
Peterpaulshaven, Russia	53	10	158	32	(?)	1	753.8	3.2	2.3	176	56	. ...	0.4

* Transactions of the Royal Society of Edinburgh, vol. xxv.

TABLE VIII—Continued.

Place.	Latitude.		Longitude.		Altitude.	Years of observation.	B_0.	B_1.	B_2.	ε_1.	ε_2.	For sea-level and gravity of the parallel of 45°. B_0.	ΔB_1.
	°	′	°	′	m.		mm.	mm.	mm.	°	°	mm.	mm.
Irkutsk, Russia	52	17	122	11	382	15	724. 2	7. 7	1. 4	14	195	760. 1	2. 9
Udskoi, Russia	54	30	134	28	(?)	1	754. 1	5. 9	0. 6	27	308	......	......
Nerchinsk, Russia	51	19	119	36	650	18	705. 1	5. 0	1. 5	3	120	765. 6	5. 4
Pekin, China	39	54	116	26	(?)	14	759. 2	9. 7	1. 0	4	204	......	......
Canton, China	23	12	113	17	(?)	10	759. 3	7. 0	1. 1	14	330	......	......
Shanghai, China	30	4	85	33	0	2	761. 7	7. 2	0. 5	6	206	760. 7	......
Tien-Tsin, China	39	9	117	16	9	1	761. 6	7. 6	3. 5	45	117	762. 0	......
Hong-Kong, China	22	16	114	10	11	6	760. 6	6. 1	0. 9	15	289	760. 2	......
Macao, Pelew Islands	22	15	113	36	(?)	1	763. 2	5. 3	0. 3	8	170	......	......
Hakodadi, Japan	41	48	140	47	46	$4\frac{5}{12}$	755. 4	2. 3	2. 4	13	194	759. 3	......
Mooltan, Hindostan	31	11	71	33	137	6	745. 7	8. 3	0. 8	3	213	756. 7	......
Bombay, Hindostan	18	54	72	48	11	14	757. 1	3. 5	0. 4	5	194	756. 5	......
Madras, Hindostan	13	4	80	19	8	27	758. 4	3. 9	0. 4	10	69	757. 3	......
Colombo, Hindostan	6	56	79	50	0	6	758. 7	0. 9	0. 3	352	69	756. 8	......
Trivandrun, Hindostan	8	31	77	0	40	$8\frac{1}{2}$	754. 1	1. 1	0. 4	349	62	755. 7	......
Upernavik, Greenland	72	48	— 55	53	5	5	752. 8	1. 5	0. 8	160	234	754. 9	......
Jacobshaven, Greenland	69	12	— 51	0	3	$9\frac{1}{2}$	755. 6	2. 2	1. 3	159	213	757. 4	......
Godthaab, Greenland	64	10	— 51	53	5	5	756. 5	2. 5	1. 8	174	224	758. 2	......
Baffin's Bay (Arctic)	72	30	(Various)		0	1	755. 6	3. 7	3. 0	146	215	757. 3	......
Van Rensselaer (Arctic)	78	37	— 73	0	0	2	756. 3	1. 9	1. 2	90	251	758. 1	......
Port Foulke (Arctic)	78	18	— 73	0	2	1	757. 5	1. 8	3. 5	47	267	759. 5	......
Port Kennedy (Arctic)	72	1	— 94	0	0	1	760. 4	3. 9	2. 6	72	213	762. 0	......
Boothia Felix (Arctic)	70	3	— 95	0	0	2	760. 5	1. 7	1. 7	108	257	762. 1	......
Mellville Island (Arctic)	75	40	—112	3	0	1	758. 4	2. 7	1. 8	75	281	760. 2	......
Port Bowen (Arctic)	73	13	— 88	54	0	1	759. 1	2. 8	3. 1	73	235	760. 7	......
Sitka, Alaska	56	50	—135	0	6	17	754. 7	3. 9	0. 6	188	36	756. 1	......
Esquimaux Harbor	48	25	—123	27	0	1	763. 3	0. 2	0. 8	124	83	763. 6	......
Astoria, Oregon	46	8	—123	48	(?)	$2\frac{1}{2}$	762. 7	0. 9	0. 2	147	114	762. 8	......
Saint John's, Newfoundland	47	35	— 52	43	0	6	759. 6	2. 5	0. 9	217	301	759. 8	......
Halifax, Nova Scotia	44	39	— 63	37	0	4	760. 0	2. 2	1. 2	214	323	760. 2	......
Do	44	39	— 63	37	0	2	756. 3	1. 6	0. 3	190	239	760. 2	......
Albion Mines, Nova Scotia	45	34	— 62	42	0	10	754. 7	0. 9	0. 2	234	148	758. 4	......
Quebec, Canada	46	48	— 71	12	0	$3\frac{1}{2}$	761. 5	1. 0	0. 6	354	94	761. 6	......
Kingston, Canada	44	14	— 76	31	0	$4\frac{1}{2}$	761. 3	0. 7	0. 4	353	105	761. 2	......
Hamilton, Canada	43	15	— 79	57	99	11	753. 5	1. 2	0. 3	242	9	762. 4	0. 4
Gardiner, Me	44	11	— 69	46	28	5	757. 0	1. 2	0. 5	290	350	759. 8	0. 1
Steuben, Me	44	28	— 67	50	15	6	759. 6	1. 1	0. 7	265	19	761 0	......
Amherst, Mass	42	22	— 72	34	81	6	755. 1	1. 6	0. 3	355	53	762. 3	0. 3
New Bedford, Mass	41	39	— 70	56	28	6	759. 5	1. 1	0. 7	277	51	761. 9	......
Nantucket, Mass	41	16	— 70	6	9	6	761. 6	1. 0	0. 6	289	40	762. 1	......
Burlington, Vt	44	29	— 73	11	106	5	751. 9	1. 1	0. 6	261	20	761. 6	0. 6
Rochester, N. Y	43	8	— 77	51	158	4	746. 7	0. 9	0. 6	354	51	761. 1	1. 1
Harrisburg, Pa	40	16	— 76	50	85	6	755. 5	1. 6	0. 5	314	62	762. 9	0. 5
Washington, D. C	38	36	— 76	58	22	11	761. 7	1. 5	0. 5	339	51	761. 7	......
Savannah, Ga	32	5	— 81	7	13	6	763. 3	1. 4	0. 6	345	38	762. 5	......
Jacksonville, Fla	30	30	— 82	0	4	6	764. 6	1. 6	0. 8	359	29	764. 0	......
Columbus, Miss	33	30	— 88	29	70	4	757. 9	2. 0	0. 8	347	30	763. 5	0. 2
Glenwood, Tenn	36	28	— 87	13	140	6	751. 0	1. 5	0. 8	339	55	764. 1	0. 4
Cincinnati, Ohio	39	6	— 84	28	155	4	749. 0	1. 8	0. 5	345	57	762. 5	0. 8
New Harmony, Ind	38	8	— 87	50	98	6	753. 5	1. 6	0. 7	346	68	761. 8	0. 5
Dubuque, Iowa	42	30	— 90	52	207	6	744. 7	1. 3	0. 8	325	70	763. 1	1. 1
Nassau, West Indies	25	4	— 77	22	4	6	763. 7	0. 9	1. 3	56	20	762. 8	......
Up Park Camp, Jamaica	18	0	— 76	56	0	6	761. 7	0. 8	0. 8	56	50	760. 1	......
Georgetown, British Guiana	6	50	— 58	8	3	11	760. 4	0. 6	0. 6	135	76	758. 8	......
Cayenne, French Guiana	4	56	— 55	39	2	6	760. 0	0. 7	0. 4	182	90	758. 2	......
Rio de Janeiro, Brazil	— 22	57	— 43	7	69	6	757. 9	3. 0	0. 5	186	42	762. 5	......
Monte Video, Uruguay	— 34	54	— 58	33	8	10	760. 4	2. 0	0. 7	196	170	760. 4	......
Saint Helena	— 15	55	— 5	42	12	5	764. 3	......	......	......	......	......	......

27. The results of the following table have been deduced from the monthly means of barometric pressure given in the reports of the Chief Signal Officer of the United States for the years 1872–'76 inclusive. The means as given in the reports are reduced to sea-level, but the results here given are also reduced to the gravity of the parallel of 45°.

TABLE IX.

Place.	Latitude.		Longitude.		Altitude.	B_0.	B_1.	B_2.	ε_1.	ε_2.
	°	′	°	′	*Feet.*	*mm.*	*mm.*	*mm.*	°	°
Augusta, Ga	33	28	—81	53	172	763.6	1.9	0.8	350	20
Baltimore, Md	39	18	76	36	45	763.2	1.8	0.2	346	33
Boston, Mass	43	20	71	3	142	761.8	0.9	0.4	308	44
Breckenridge, Minn	46	16	96	38	966	762.1	3.9	0.8	5	93
Buffalo, N. Y	42	53	78	55	666	761.1	1.2	0.3	351	126
Burlington, Vt	44	29	73	11	241	761.5	1.6	0.3	329	58
Cairo, Ill	37	0	89	0	367	763.3	2.6	0.5	346	29
Cape May, N. J	39	0	74	58	14	763.0	1.5	0.4	344	24
Charleston, S. C	32	45	79	57	61	763.5	1.6	0.8	353	20
Chicago, Ill	41	52	87	35	668	761.9	2.0	0.5	354	65
Cincinnati, Ohio	39	6	84	30	596	763.1	2.4	0.4	346	38
Cleveland, Ohio	41	30	81	36	688	761.8	1.5	0.3	358	82
Davenport, Iowa	41	30	90	36	603	762.4	2.8	0.6	352	55
Detroit, Mich	42	18	83	0	644	761.5	1.7	0.5	359	94
Duluth, Minn	46	48	92	6	643	761.5	2.3	0.4	10	134
Escanaba, Mich	46	36	87	6	619	761.3	1.4	0.6	1	104
Fort St. Michael's, Alaska (2 years' observations)	63	28	161	45	0	759.8	2.1	1.5	34	70
Galveston, Tex	29	19	94	46	39	762.3	1.9	0.8	353	7
Grand Haven, Mich	43	5	86	13	616	761.4	1.6	0.3	350	90
Indianapolis, Ind	39	42	86	6	747	762.2	2.3	0.3	346	57
Jacksonville, Fla	30	15	82	0	23	763.5	1.6	0.9	2	11
Keokuk, Iowa	40	18	91	30	584	761.4	2.8	0.4	353	68
Key West, Fla	24	36	81	48	32	762.3	1.1	1.0	35	25
Knoxville, Tenn	35	56	83	58	993	763.2	2.3	0.6	347	12
Lake City, Fla. (3 years' observations)	30	6	82	42	....	762.9	1.4	0.9	352	0
Leavenworth, Kans	39	21	94	44	813	761.5	3.6	0.5	350	49
Louisville, Ky	38	0	85	25	496	762.5	2.4	0.4	348	46
Lynchburg, Va	37	18	85	54	651	763.3	2.1	0.5	344	12
Marquette, Mich	46	33	87	23	666	761.3	1.5	0.7	27	95
Memphis, Tenn	35	8	88	0	299	763.5	2.6	0.5	347	20
Milwaukee, Wis	43	3	87	57	672	762.0	1.6	0.4	346	84
Mobile, Ala	30	42	87	59	39	763.6	1.9	0.8	0	5
Nashville, Tenn	36	10	86	49	504	763.4	2.6	0.5	346	24
New London, Conn	41	22	72	9	38	762.5	1.0	0.3	323	63
New Orleans, La	29	57	90	0	56	762.9	1.8	0.7	358	5
New York, N. Y	40	42	74	1	166	762.7	1.3	0.4	339	49
Norfolk, Va	36	51	76	19	56	763.2	1.4	0.4	330	308
Omaha, Nebr	41	26	96	0	1055	760.6	3.6	0.5	356	62
Oswego, N. Y	43	28	76	35	299	761.7	0.9	0.5	343	94
Philadelphia, Pa	39	57	75	12	47	763.2	1.6	0.3	344	35
Pittsburgh, Pa	40	32	80	2	791	762.0	2.2	0.7	357	63
Portland, Me	43	40	70	14	584	761.2	0.4	0.4	297	56
Portland, Oreg	45	30	122	27	90	764.4	0.4	0.6	45	260
Punta Rassa, Fla	27	0	82	18	17	763.2	1.1	0.8	24	24
Rochester, N. Y	43	8	77	51	584	761.2	1.2	0.4	340	320
San Diego, Cal	32	44	117	6	62	761.8	1.8	0.4	37	298
San Francisco, Cal	37	48	122	26	60	762.5	1.6	0.2	32	290
Savannah, Ga	32	5	81	8	71	763.6	1.8	0.8	356	9
Shreveport, La	32	30	93	45	229	762.5	2.2	0.5	359	11
Saint Louis, Mo	38	37	90	16	557	762.5	2.5	0.5	348	55
Saint Paul, Minn	44	53	93	5	794	761.0	2.7	1.0	358	116
St. Paul's Island, Alaska (4 years' observations)	57	3	170	0	0	755.9	3.0	1.6	159	73
Toledo, Ohio	40	39	83	32	531	761.7	1.9	0.3	346	36
Vicksburg, Miss	32	24	91	0	280	764.1	2.4	0.6	350	351
Washington, D. C	38	53	77	1	106	763.0	2.0	0.3	355	340
Wilmington, N. C	34	11	—78	10	74	763.5	1.6	0.7	353	0

28. With the values of B_0 in the preceding tables, Charts I and II have been constructed, showing the mean barometric pressure, reduced to the gravity of the parallel of 45°, for the northern and southern hemispheres, by giving the positions of the isobars for each 2^{mm}. These isobars represent the mean pressures very accurately in Europe and the United States of America, the greater part of the North Atlantic, and many other places where the observations suffice to lay them down accurately; but throughout all the interior of Asia, Africa, and South America, and the greater part of the great oceans, where there are but few observations, and these not reliable in many cases on account of the uncertainty of altitude above sea-level, and the lack of comparisons of the barometers used with any standard of comparison, of course the true positions of these lines are uncertain, but nowhere entirely conjectural, since we can derive much aid from theory and analogy in laying down these lines for those parts of the earth's surface for which we have few or no observations. As reliable observations multiply, and are obtained for those parts of the earth for which we have yet no observations, of course the positions of the lines as laid down in these charts will be found to be somewhat in error for all places for which we have not yet sufficient observations to determine them; but it is thought that the errors in general will be found to be small.

The arrows on these and the following charts denote the prevailing directions of the wind These are given, not from observation, but from theoretical considerations of the relations between the gradients and the directions and velocities of the winds, to be explained in a subsequent part of this work. The winds, as represented on these charts, are the resultants of all the winds for the whole year, which can now be laid down more accurately from a knowledge of the isobaric lines than from observations, which in most parts of the earth consist merely in the observation of the relative frequency of the winds from the different points of the compass. The prevailing direction of the wind, as obtained from such observations, may be very different from the resultant obtained by Lambert's formula from observations of the true velocities and directions of the wind through the year.

29. With the values of B_1 in the preceding tables, reduced to sea-level by means of the values of ΔB_1 where the monthly means of the observations were not given for sea-level, Charts III and IV have been constructed, representing the coefficients of the annual inequality of barometric pressure over the whole globe. These coefficients are accurately represented by the charts for all portions of the earth where the observations were sufficient for their determination; but, of course, there is the same uncertainty with regard to them where few or no observations have been made which there is with regard to the mean pressures.

Where the signs of these coefficients as given on the charts are positive, the maximum of the barometric pressure occurs in the winter and the minimum in the summer. It is seen from the chart of the northern hemisphere that these signs are mostly positive on land and negative on the ocean, especially on the middle parallels of latitude. This arises from the higher temperature of the air in summer and lower temperature in winter on land than on the ocean. The line of no annual inequality of barometric pressure passes over Norway and Sweden and a little east of London, touching upon France and Portugal, having its most southern point in the middle of the Atlantic, a little south of the parallel of 20°, and then, curving northward, passes over the eastern part of New England in America.

On account of the great extent of continent and the great extremes of temperature in the interior of Asia, this coefficient of the annual inequality amounts to about 10^{mm}, or a range of 20^{mm} between winter and summer, while in America it amounts at the maximum to only about one-third as much. This difference between Asia and North America does not depend so much upon the difference in the extremes of temperature of the two countries, which is inconsiderable, as upon the difference in the extent of the two continents.

The lines on Charts III and IV represent the gradients which in winter have to be added to the gradients given on Charts I and II to obtain the gradients for that season, and these in summer are completely reversed, and hence the steeper these gradients the greater are the monsoon influences in the different parts of the globe. These, it is seen, are very great in the southern part of Asia.

In the southern hemisphere, on account of the small extent of land and the small range of temperature between winter and summer, the coefficient of the annual inequality of barometric pressure is small and negative so far as we have observations to determine it, and nearly the same in all longitudes on the same parallel of latitude. Its being negative shows that the maximum

occurs in winter, that is, during the summer of the northern hemisphere. About the parallel of 55°, this coefficient seems to vanish, beyond which it probably becomes positive, making the maximum of pressure in the summer as in the northern parts of the Atlantic and Pacific Oceans of the northern hemisphere.

30. The values of ϵ_1 in the preceding tables are very various, depending upon the want of sufficient observations in many cases to eliminate the abnormal inequalities and bring out the true value, especially in such cases as give a small value of the coefficient B_1, which is often less than the possible error of observation, when the value of ϵ_1 is of course indeterminate, and may have any value whatever. Taking the average of all the values of ϵ_1 in Table VI belonging to coefficients greater than 3.0^{mm}, we get $\epsilon_1 = 9°$, which makes the maximum of barometric pressure in Europe occur about the 9th of January, a little earlier than the minimum of temperature. This is perhaps the most probable value of ϵ_1 for all stations in Europe, the variations from this value of ϵ_1 in the different stations being merely possible errors of observation, though they may possibly depend in some measure upon local causes. To this value, the values of ϵ_1 for other places in Europe in the other tables seem also to point in cases in which the coefficient is sufficiently large for the values of ϵ_1 to be determined approximately from observation.

Where stations have great altitude above sea-level, as in the case of Höhenpeisenburg in Table VII, the value of ϵ_1 is such as to make the maximum of the barometric pressure occur in summer instead of winter, in which case we can change ϵ_1 by 180°, and consider the value of B_1 as negative. Applying the correction then in the column headed by ΔB_1 to reduce this coefficient to sea-level, it becomes positive, and makes the maximum of pressure fall in the winter. In the case of Höhenpeisenburg, we get $-1.9^{mm} + 3.3^{mm} = 1.4^{mm}$ for the coefficient of annual inequality, with the value of $\epsilon_1 = 228° - 180° = 48°$, making the maximum occur after the middle of February. In applying the reduction to sea-level, ΔB_1, it is supposed for convenience that the maximum of pressure coincides with the minimum of temperature, which, we have seen, is not strictly correct, but the errors in these small reductions arising from this cause are generally very small.

In all cases in which the values of ϵ_1 are such as to throw the maximum of barometric pressure into the time of summer of the northern hemisphere, as in the northern parts of the Atlantic and Pacific Oceans and in the southern hemisphere generally, the values of B_1 as entered in the Charts III and IV are considered negative, and in all such cases the values of ϵ_1 must be diminished by 180°, or the negative sign of the coefficient on the chart changed to the positive sign if used with the average value of ϵ_1 given by the tables in such cases, which does not generally differ much from 200°, throwing the maximum of barometric pressure in July.

If we take the average of all the values of ϵ_1 in Table IX, deduced from the observations of the Signal Service of the United States, giving them weights in proportion to the magnitudes of B_1, and excluding the stations on the Pacific coast, we get $\epsilon_1 = 353°$ for the stations north of the parallel of 40° and $\epsilon_1 = 351°.1$ for the stations south of that parallel; and hence we may put for the United States, except the Pacific coast, $\epsilon_1 = 352°$. This makes the maximum of barometric pressure occur about the 23d of December, and about sixteen days earlier than in Europe, and in both places considerably earlier than the time of the minimum of temperature. This is most probably caused by the greater amount of aqueous vapor in the atmosphere in the spring than in the fall, which causes the maximum of barometric pressure to be earlier.

31. In addition to the *annual* inequality of barometric pressure, there is also a very small semi-annual inequality, as may be seen from an inspection of the columns in the preceding tables headed by B_2 and ϵ_2. The values of B_2 as given are mostly of the order of the probable, or, at least, possible, errors of the results, as may be seen from the scattering values of ϵ_2, and hence do not indicate real terms; but if we examine all the larger values of B_2, we find that the corresponding values of ϵ_2 are such as to indicate real terms, and give a maximum of inequality in the middle of winter and summer, and a minimum in the spring and fall. The coefficient of this inequality seems to be generally less than 1.0^{mm}, but in some places, especially toward the north pole, it appears to be much greater.

The average of these coefficients in Table IX, from the observations of the Signal Service of the United States, excluding the stations on the Pacific coast, give for the stations south of the parallel of 35°, $B_2 = 1.02^{mm}$, and the corresponding average of the values of ϵ_2, giving each weight in proportion to the magnitude of the coefficient, is 8°, indicating maxima about the 4th of January and July. In the same manner, we get for the stations between the parallels of 35° and 40°,

$B_2 = 0.53^{mm}$, and $\epsilon_2 = 19^\circ.6$. For those stations north of the parallel of 40°, we get $B_2 = 0.48^{mm}$ and $\epsilon_2 = 45^\circ.4$. The coefficient, therefore, seems to diminish in the United States with the increase of latitude, and the times of maxima to become later, being, in the northern part of the United States, about the 23d of January and July.

32. If we take from Charts I and II the mean barometric pressures for each fifth parallel of latitude and each tenth degree of longitude, and take the averages with regard to the different longitudes, we get the results contained in the first column, headed B_0, in Table X, which are the mean pressures for the corresponding latitudes in the first column. It is seen that there is a minimum pressure about 6° north of the equator, a maximum in the northern hemisphere near the parallel of 35°, and in the southern hemisphere near the parallel of 28°. There is also a minimum at the parallel of 65° in the northern hemisphere, arising from the two great depressions of barometric pressure in the northern parts of the Atlantic and Pacific Oceans.

From the differences of B_0, with the irregularities a little smoothed off, the gradients in the column headed G are obtained, which express, in millimeters, the differences of barometric pressure, corresponding to a distance of one degree of a circle having the mean radius of the earth, or 111111 meters.

By taking the averages of all the values of B_1, taken from Charts III and IV, for each tenth degree of longitude, we get the results contained in the fourth column of Table X, from the differences of which, smoothed off a little, we get the corresponding gradients in the column headed by g. These latter results, added to those of the mean pressures, give the pressures and gradients for January, and subtracted give those for July. From what we have seen in § 30, the maxima and minima for the average of all longitudes occur about the first of these months, and before the maxima and minima of temperature.

TABLE X.

Lat.	Annual mean.		Annual inequality.		January.		July.	
	B_0.	G.	B_1.	g.	B_0.	G.	B_0.	G.
°	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
80	760.5	....	−0.06	....	760.4	....	760.6	....
75	760.0	−0.19	+0.19	+0.04	760.2	−0.15	758.8	−0.23
70	758.6	−0.14	0.36	0.05	759.0	−0.09	758.2	0.19
65	758.2	+0.01	0.63	0.06	758.8	+0.07	757.6	−0.05
60	758.7	0.15	0.97	0.06	759.7	0.21	757.7	+0.09
55	759.7	0.20	1.26	0.05	761.0	0.25	758.4	0.15
50	760.7	0.18	1.41	0.03	762.1	0.21	759.3	0.15
45	761.5	0.15	1.53	0.02	763.0	0.17	760.0	0.13
40	762.0	+0.07	1.61	+0.01	763.6	+0.08	760.4	+0.06
35	762.4	−0.03	1.66	0.00	764.1	−0.03	760.7	−0.03
30	761.7	0.18	1.66	−0.01	763.4	0.19	760.0	0.17
25	760.4	0.25	1.61	0.03	762.0	0.28	758.8	0.22
20	759.2	0.21	1.41	0.06	760.6	0.27	757.8	0.15
15	758.3	0.13	1.05	0.09	759.3	0.22	757.3	−0.04
10	757.9	−0.03	+0.50	0.11	758.4	0.14	757.4	+0.08
5	758.0	+0.01	−0.05	0.12	758.0	0.11	757.9	0.13
0	758.0	0.04	0.63	0.12	757.4	−0.08	758.6	0.16
− 5	758.3	0.11	1.18	0.11	757.1	0.00	759.5	0.22
10	759.1	0.20	1.70	0.08	757.4	+0.12	760.8	0.28
15	760.2	0.26	2.00	0.06	758.2	0.20	762.2	0.32
20	761.7	0.29	2.22	−0.03	759.5	0.26	763.9	0.32
25	763.2	+0.18	2.36	0.00	760.8	+0.18	765.6	+0.18
30	763.5	−0.08	2.22	+0.03	761.3	−0.05	765.7	−0.11
35	762.4	0.30	1.85	0.06	760.6	0.25	764.2	0.35
40	760.5	0.51	1.41	0.07	759.1	0.44	761.9	0.58
45	757.3	0.73	1.00	0.09	756.3	0.64	758.3	0.82
50	753.2	0.91	−0.50	0.10	752.7	0.81	753.7	1.01
55	748.2	0.97	0.00	+0.10	748.2	−0.87	748.2	−1.07
60	743.4	0.83	....	....	....	....	....	....
65	739.7	−0.56	....	....	....	....	....	....
−70	738.0	....	....	....	....	....	....	....

With the values of G in this table, the values of $D_u P$ contained in equations (15), and in expressions deduced from them in the following chapter, are readily obtained.

33. Chart V shows, by isobaric lines, the mean pressure of the atmosphere in the northern hemisphere for January, in millimeters, reduced to the gravity of the parallel of 45°, and, by arrows, the prevailing directions, or rather the directions of all the resultants for the month. These latter are inserted, as in the case of Charts I and II, from theoretical considerations of the relations between the winds and the isobars, and not from results deduced from actual observations.

Chart VI shows the same for the month of July. The epochs of maxima and minima on the earth's surface generally, from what has been stated, are nearly the 1st of January and July respectively, and not at the times of the least and greatest temperatures.

On the first of these charts there are two areas of great barometrical depressions over the northern parts of the great oceans, and two areas of high barometer over each of the continents, and consequently having the isobars mostly crowded closely together, with corresponding strong prevailing winds. On the last of these charts, for July, in consequence of the reversal of the annual inequality, it is seen that these areas of low and high barometers are very much smoothed off, and consequently the isobars are much separated, with corresponding small velocities of the prevailing or resultant winds; for the winds in the same latitudes are very nearly inversely as the distances between the isobars, as will be explained in the second part of this work.

As the barometric pressures given on the chart are the observed pressures reduced to those of the gravity of the parallel of 45°, in comparing observed pressures in any part of the world with those given by the charts, the same reduction must first be made. The part of gravity depending upon latitude is expressed by the last term in the expression of g in (13). The effect upon the height of the mercurial column is inversely as that upon gravity, and hence the observed column is too low toward the poles and too high toward the equator. The correction, therefore, to be applied to the observed height for the pressure of 0.76^m is $0.76^m \times 0.00284 \cos 2\theta$, which can be used for all parts of the earth's surface without material error. This reduction is given for each fifth degree of latitude in the following—

TABLE.

Latitude.	Reduction.	Latitude.	Reduction.	Latitude.	Reduction.
°	*mm.*	°	*mm.*	°	*mm.*
0	− 2.16	30	− 1.08	60	+ 1.08
5	2.12	35	0.74	65	1.39
10	2.03	40	− 0.37	70	1.65
15	1.87	45	0.00	75	1.87
20	1.65	50	+ 0.37	80	2.03
25	− 1.39	55	+ 0.74	85	+ 2.12

CHAPTER III.

THE GENERAL MOTIONS OF THE ATMOSPHERE.

34. Under the head of "The general motions of the atmosphere" are included all those motions which extend as a system over the whole globe, and depend upon differences of temperature between the equatorial and the polar regions at all seasons, and hence they comprise not only the mean motions of the atmosphere, but likewise the changes in these motions depending upon the seasons; but they do not include those motions or disturbances depending upon permanent differences, for the time, of temperature in different longitudes, upon local disturbances of temperature or of density from any cause, or upon the irregularities of the earth's surface. The conditions to be satisfied in this case are those of equations (15), in which, since differences of temperature in longitude are not considered, $D_v \log a'$ vanishes, and consequently the last term of the second equation. The complete solution of these equations is impossible, both on account of their complexity and the uncertain element of friction entering into them, the laws and the amount of which are unknown. Many important results, however, may be deduced from their consideration and solution in special cases, from which approximate results may be obtained by neglecting the effects of friction, and the latter, with the aid of observation, may be shown in most cases to be very small.

If the temperature and amount of aqueous vapor upon which a depends were the same over all parts of the earth's surface, $D_u a^1$ and $D_v a^1$ in (15) would vanish, and it is readily seen that the conditions of (15) in this case are satisfied with $D_t u = 0$ and $D_t v = 0$, and consequently with a state of rest and of uniform pressure over the whole globe. And if the atmosphere were set in motion by any external impulse, this motion, in the case of friction, would be speedily destroyed, and a state of rest ensue. *There can be no winds, then, without a disturbance of the static equilibrium by means of a difference of temperature or of aqueous vapor in different parts of the atmosphere.*

35. In the case of no friction, where a is independent of longitude, it is evident that P′ is likewise independent of longitude, and the first member of the second of (15) must vanish, as well as the last two terms of the second member, and the equation is reduced to—

$$0 = D_t^2 v + 2 \cos \theta \, (n + D_t \omega) \, D_t u$$

Since we have $u = r \, D_t \theta$ and $v = r \sin \delta \, D_t \varphi$, this equation may be expressed in the following form:—

$$2 \sin \theta \cos \theta \, (n + D_t \varphi) \, D_t \theta + \sin^2 D_t^2 \varphi = 0$$

The integral of this equation is—

$$\sin^2 \theta \, (n + D_t \varphi) = c$$

in which c is a constant depending upon the initial east or west velocity, or value of $D_t \varphi$, of the particle supposed to be not influenced in its motions by contiguous parts, as implied by putting $F_v = 0$ in the original equation in (15).

If we put θ' and v for the initial values of θ and $D_t \varphi$, we have—

$$c = \sin^2 \theta' \, (n + v)$$

We shall therefore have, if we suppose the particles to have such an action upon each other as to reduce, in time, the motions of all the particles of the atmosphere upon the same parallel of latitude to the same, and that there is no resistance between the earth's surface and the atmosphere,—

$$(37) \quad . \; . \; . \; . \; . \; . \; . \; . \quad \int \sin^2 \theta \, (n + D_t \varphi) = \int_m c = \tfrac{2}{3} \, (n + v') \, m$$

in which m is the mass of the atmosphere, and—

$$v' = \frac{1}{m} \int_m \sin^2 \theta \, v$$

If the initial state of the atmosphere is that of rest relative to the earth's surface, we have v, and consequently v', $= 0$.

The first member of (37) expresses in terms of the earth's radius the sum of all the areas described in a unit of time by a line drawn from the earth's axis to each particle of the atmosphere, and this sum must always remain the same since no mutual actions of the particles upon each other can change it, and the velocity of each particle at the same distance from the earth's axis, that is, upon the same latitude, must always be the same after they have been brought to this state by their mutual actions upon each other. We shall then have—

$$(38) \quad . \quad . \quad . \quad . \quad . \quad (n + D_t \varphi) = \frac{2\,n\,(n + v')}{3 \sin^2 \theta}$$

The first member of this equation represents the angular velocity of a particle of atmosphere around the earth's axis depending upon the velocity of the earth's rotation n and the angular velocity $D_t \varphi$ relative to the earth's surface, and this velocity, it is seen, as the particle moves toward or from the pole, must be inversely as $\sin^2 \theta$, and consequently inversely as the square of the distance from the axis of rotation, and this is independent of any law governing the motion toward or from the pole, just as in the case of the planets, or the motions of any free body controlled by a central force, whatever may be the law of that force. Multiplying both members of (38) by $r \sin \theta$, it becomes the expression of the linear velocity.

From (38) we get, in the case of a state of initial rest relative to the earth's surface, in which case $v' = 0$,—

$$(39) \quad . \quad . \quad . \quad . \quad . \quad . \quad \begin{cases} D_t \varphi = \left(\dfrac{2}{3 \sin^2 \theta} - 1\right) n \\ D_t v = r \sin \theta \, D_t \varphi = r\,n \left(\dfrac{2}{3 \sin \theta} - \sin \theta\right) \end{cases}$$

The first of these expresses the angular and the second the linear velocity of eastward motion relative to the earth's surface.

If we put $D_t \varphi = 0$, the first of (39) gives—

$$(40) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \sin \theta = \frac{2}{3}$$

from which we get $\theta = 54° \, 44'$, corresponding to the parallel of $35° \, 16'$, where there is no east or west motion to the air. All velocities between this parallel and the pole are positive, and those between this parallel and the equator negative.

If we substitute the preceding value of $D_t \varphi$ in the first of (15), and neglect the effect upon P′ of a difference of density, and of the inertia of the fluid represented by $D_t^2 u$, we get, since $r\,D_u \log P'$ is equal to $D_\theta \log P'$, and F_v vanishes in the case of no friction,—

$$\frac{1}{a'} D_\theta \log P' = r^2 n^2 \sin \theta \cos \theta \left(\frac{4}{9 \sin^4 \theta} - 1\right)$$

By integration, regarding a' as constant, we get—

$$\frac{1}{a'} \log P' = - r^2 n^2 \left(\frac{2}{9 \sin^2 \theta} + \tfrac{1}{2} \sin^2 \theta\right) + C$$

in which, if we put P″ for the value of P′ at the equator, we have—

$$C = \frac{1}{a'} \log P'' + \frac{13}{18} r^2 n^2$$

Hence,—

$$(41) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \log P' = \log P'' + M a' r^2 n^2 \left(\frac{13}{18} - \frac{2}{9 \sin^2 \theta} - \frac{1}{2} \sin^2 \theta\right)$$

in which the factor M, the modulus of common logarithms, must be used when these are used.

In inelastic fluids we have merely to substitute $P' = gh$ for $\log P'$ in all the preceding equations. Hence, in this case, we get from (41), by putting the first member equal 0, a condition for determining the latitude where the pressure, and consequently h, the height of the fluid, vanishes, and hence a condition for determining the polar limit of the fluid. This limit depends upon the value of P″, the pressure or the height of the fluid at the equator, and the greater this is the higher the latitude, where h, the height of the fluid, becomes 0.

With the value of $r\,n$ (§ 14), and the value of $a' = a_0$ given by (20), which is the value belonging to the temperature of 0°, we get $\mathrm{M}a'\,r\,n^2 = 1.1946$. With this value, and the special value of $\sin^2\theta = \frac{2}{3}$ in (40), belonging to the latitude where the pressure is a maximum, we get—

$$\log \mathrm{P}' = \log \mathrm{P}'' + 0.06636$$

If we suppose P″, the pressure or value of P′ at the equator, equal to 0.76^{m}, we get for the maximum pressure near the parallel of 35°—

$$\log \mathrm{P}' = 9.88081 + 0.06636 = 9.94717$$

Hence, at this parallel, $\mathrm{P}' = 0.88545^{\mathrm{m}}$, or 0.12545^{m} greater than at the equator. There is, therefore, in this case a great depression or diminution of the pressure at the equator, an accumulation having its maximum near the parallel of 35°, and almost a vacuum near the poles.

With the value of $r\,n$ in § 14, the second of (39) gives at the equator, where $\sin\theta = 1$,—

$$\mathrm{D}_t\, v = -\,154.76^{\mathrm{m}}$$

for the velocity per second of the atmosphere at the equator in this case, or a westward velocity of about 557 kilometers per hour. Toward the poles, where $\sin\theta$ in the denominator of one of the terms in the expression of $\mathrm{D}_t\, v$ (39) becomes small, the eastward velocity becomes very great.

36. We know from observation that in the case of nature in which there is friction, the value of $\mathrm{D}_t\,\varphi$, the angular velocity of the atmosphere relative to the earth's surface, is very small in comparison with n, the angular velocity of rotation, and hence may be neglected in comparison with it. In the case, therefore, under consideration now, in which the first member of the second of (15) vanishes, and also the last term of the second member, we have very nearly—

$$(42) \quad . \;.\; .\; .\; .\; .\; .\; .\; .\; . \quad 2\,n \cos\theta\, \mathrm{D}_t\, u = -\,(\mathrm{F}_v + \mathrm{D}_t^2\, v)$$

The first member expresses the deflecting force depending upon the earth's rotation on its axis, and upon $\mathrm{D}_t\, u$, the velocity along the meridian, and it is this force alone which overcomes the friction and inertia of the air represented by the two terms in the second member. At the equator, where $\cos\theta = 0$, we have—

$$\mathrm{D}_t^2\, v = -\,\mathrm{F}_v \qquad \text{or} \qquad \mathrm{D}_t\, v = -\,\mathrm{F}_v\, t$$

As F_v is negative, it tends to destroy all motion which the air might have at the equator, and hence there can be no east and west motion there in the case we are now considering, in which only differences of density between the equatorial and polar regions are considered. Since $\mathrm{D}_t\, u$ in (42) becomes very small toward, and vanishes at, the poles, we must for the same reason have a calm about the poles.

37. If the motions of the atmosphere were not resisted by the earth's surface, the results of the preceding section for the case of no friction could be at once applied to them without any modifications; hence toward the poles there would be a very rapid motion of the atmosphere eastward and in the equatorial regions toward the west, and the atmosphere would be very much depressed at the equator, and almost vanish from the polar regions, and become very protuberant about the parallels of 35°. Although these results, when applied to the atmosphere, must be very much modified on account of the resistances of the earth's surface, yet they will be of great advantage in explaining its general motions; for as there can be no resistance until there is motion, the atmosphere must have a tendency to assume, in some measure, the same motions and figure of outline as in the case of no resistances. Hence toward the poles, the general motions of the atmosphere at the earth's surface must be toward the east, and in the torrid zone toward the west; but as these motions, in consequence of the resistances, are small in comparison with those in the case of no resistances, instead of the atmosphere having a great depression at the equator, and almost entirely receding from the poles, there are only comparatively small depressions, as represented in Chart VII, in which the outline of the part representing the atmosphere must be regarded merely as a stratum of equal density in the upper regions. That there are really such depressions at the equator and the poles is shown by the barometric pressures given in Table X, for the pressures are less at the equator and toward the poles, especially the south pole, than in middle latitudes, although the density of the atmosphere at the poles is much greater on account of the lowness of the temperature, and hence there must be considerable polar depressions in the strata of equal density.

rt VII is intended to represent the mean annual vertical or horizontal surface motions of the atmosphere in the case of a homogeneous surface over the whole globe, of either all water or all land of the same unevenness, and with the same temperatures at corresponding parallels of the two hemispheres. Hence the equatorial calm-belt coincides with the equator, and the other two calm-belts are found on corresponding parallels, and the whole system of the winds in the two hemispheres is exactly similar. On account, however, of the unequal distribution of land and water in the two hemispheres, these calm-belts are somewhat displaced, being all moved a little toward the north pole; and on account of the unequal distribution of temperature in the different longitudes corresponding to the same parallels of latitude in the same hemisphere, arising from the unequal distribution of land and water, these calm-belts and the general system of the winds are very much deranged, especially in the northern hemisphere, as represented in Charts I and II.

38. As the motion of the atmosphere is east toward the poles and west near the equator, somewhere between the equator and the poles there must be a parallel of latitude where there is no east or west motion. This, in the case of no resistance, and upon the hypothesis of an initial state of rest, we have found to be nearly the parallel of 35°; but, in the case of nature, in which there are frictional resistances at the earth's surface to the motions of the atmosphere, this parallel depends upon the law of the resistances and the velocities of motion, and hence it cannot be accurately determined from theory. It is evident, however, that the east and west motions of the atmosphere at the earth's surface must be such that the sum of the resistances of each part of the earth's surface multiplied into its distance from the axis of motion must equal 0, else the velocity of the earth's rotation would be continually either accelerated or retarded, which cannot arise from any mutual action between the earth's surface and the surrounding atmosphere. Now, as the part of the earth's surface where the motion of the atmosphere is west is much farther from the axis than the part where it is east, it is reasonable to suppose that the parallel of no east and west motion must be nearer to the equator in this case than the parallel of 35°, unless the eastward velocities toward the poles were very much greater than the westward velocities toward the equator. This is known to be the position of this parallel from observation. In speaking of the east and west motions of the atmosphere, of course only one component of the real motions is understood.

39. Since there is an eastward motion of the atmosphere in the polar regions and a westward motion nearer the equator, the protuberance of the outline of the atmosphere and the increase of pressure in the middle latitudes, with a maximum near the parallel of 30°, is readily explained by the principle given in § 13; for, according to this principle, the eastward motions in both hemispheres give rise to a deflecting force, arising from the earth's rotation toward the equator, and the westward motions nearer the equator to a deflecting force toward the poles, and hence there must be an accumulation of atmosphere having its maximum between these east and west motions.

40. The increase of pressure arising from the accumulation of atmosphere near the parallels of 30° gives the atmosphere at the earth's surface a tendency to flow from beneath this accumulation both toward the equator and the poles, since the motions, and consequently the deflecting forces arising from these motions, and causing this accumulation, are much less near the surface, where friction is greatest, than in the higher strata. But on account of the greater density of the atmosphere toward the poles, it has a tendency also to flow, at the earth's surface, from the poles toward the equator. Between the parallel of greatest pressure and the equator these tendencies combine and produce a strong surface-current which, combining with the westward motion there, gives rise to the well-known northeast wind in the northern and southeast wind in the southern hemisphere, represented on Chart VII, called the trade-winds. But between the parallels of greatest pressure and the poles, these tendencies are opposed to each other, and the one arising from the accumulation of atmosphere being the greater in the middle and polar latitudes and near the earth's surface causes the atmosphere there to flow toward the poles; and this motion, combining with the general eastward motion of the atmosphere in these latitudes, gives rise to the southwest winds in the northern and the northwest winds in the southern hemisphere, which prevail in these latitudes, as represented on Chart VII.

41. Since the atmosphere at the parallel of greatest pressure has no barometric gradient, it can have no north or south motion there at the surface, and consequently $D_t u$ in (33) vanishes, and there is no force arising from the earth's rotation to overcome the friction at the surface; and hence

there can be no east and west motion there, and we have what are called the tropical calm-belts. These calm-belts, therefore, must coincide with the belts of maximum pressure, which, for the average of all longitudes, it is seen from Table X, is near the parallel of 35°, being a little farther from the equator in the northern hemisphere than the southern, on account of the unequal distribution of land and water; the land with high mountain-ranges diminishing the east and west motions in the northern hemisphere, upon which the positions of these calm-belts depend.

From what precedes, the mean motions of the atmosphere, unobstructed by inequalities of surface, such as continents and mountain-ranges, would be at the earth's surface nearly as represented in Chart VII, and the calm-belts have positions very nearly as there represented.

42. From the first of (15), we get, by neglecting $D_t\varphi$ in connection with n,—

$$D_t v = \frac{\frac{1}{a'} D_u \log P' - g h \frac{D_u a'}{a'} + D_t^2 u + F_u}{2 n \cos \theta}$$

With regard to the value of $D_t^2 u$ arising from the inertia of the atmosphere, we know that in all the general motions of the atmosphere it is very small. The interchanging motions of the atmosphere between the equatorial and the polar regions arising from the disturbance of static equilibrium on account of a difference of temperature consist, except near the earth's surface, of a motion in the upper regions toward the poles, and in the lower regions of a motion from the poles, the whole circuit of this motion being performed in a long period of time. Hence the rate of increase or decrease of velocity in any part of the circuit, upon which the value of $D_t u$ depends, is very small.

The greatest velocity of these motions is perhaps not more than 10 kilometers per hour, or 2.778^m per second, and if we suppose all this velocity to have been generated in 24 hours, or 86400 seconds, we shall have, by putting G for the force required to overcome the inertia,—

$$G = D_t^2 u \qquad \text{and} \qquad D_t u = G\,t$$

With the value of $D_t u = 2.778^m$, above, and $t = 86400$ seconds, we get—

$$G = \frac{2.778^m}{86400}$$

Now we have g, the accelerating force of gravity, equal to 9811^{mm}, and hence we have—

$$\frac{G}{g} = 0.00000032775$$

This is the ratio between the horizontal force required to overcome the inertia of the atmosphere and the vertical force of gravity, and corresponds to a gradient in the atmosphere of 0.364^m in the distance of one degree, or 111111^m. This multiplied into the ratio between the density of air and mercury, $\frac{1}{10511}$, gives a barometric gradient of nearly 0.0035^{mm}, a quantity which might generally be neglected in comparison with the gradients upon which velocities generally depend.

With the preceding value of G, if we put $\Delta D_t v$ for the effect of this term upon $D_t v$, we get—

$$\Delta D_t v = \frac{2.778^m}{86400 \times 2 n \cos \theta}$$

With this expression, we get, on the parallel of 45°, with the value of n in § 14, $\Delta D_t v = 1.126^{km}$ per hour. Even this quantity would be of little consequence in estimating the approximate velocities of the general motions of the atmosphere; but the effect of the term in question must be very much less than this, since, in the slow interchanging motions between the equatorial and polar regions, the time in which a particle at rest in its extreme northern or southern position arrives at its maximum velocity must be very much more than 24 hours, as supposed above. The effect of this term then must be extremely small. Of course, this applies only to the slow general motions between the equatorial and polar regions, and not to those belonging to cyclonic disturbances of the atmosphere.

For the same reasons, the term $D_t^2 v$ is always very small, and in the general motions of the atmosphere may be neglected without sensible error. Equation (42) therefore furnishes us with a measure of the amount of friction when we know the value of $D_t u$.

If we put—

s = the motion of a particle of atmosphere;

F_s = the frictional resistance in the direction of that motion; and

i = the inclination of s to v, the eastward motion:

we have—

$$F_v = F_s \cos i \qquad F_u = F_s \sin i$$
$$D_t v = D_t s \cos i \qquad D_t u = D_t s \sin i$$

By means of these equations and (42), putting $D_t^2 v = 0$, we get—

$$F_u = 2 n \cos\theta\, D_t u \tan i = 2 n \cos\theta\, D_t v \tan^2 i$$

With this value of F_u we get from the preceding equations for the eastward component of velocity—

$$(43)\ldots\ldots\quad D_t v = \frac{\frac{1}{a'} D_u \log P' - g h \frac{D_u a'}{a'} + D_t^2 u}{2 n \cos\theta} \cos^2 i$$

Hence we get for the velocity of motion—

$$(43')\ldots\ldots\quad D_t s = \frac{\frac{1}{a'} D_u \log P' - g h \frac{D_u a'}{a'} + D_t^2 u}{2 n \cos\theta} \cos i$$

In the case of no friction, or where the effect of friction is neglected, we must put $\cos i = 1$.

When the direction of the wind, or, in other words, the value of i, is known from observations, the effect of friction in the preceding expressions is known; but when this direction is not known, we must neglect this effect, and put $\cos i = 1$. At the earth's surface, especially in the trade-wind zones, the value of i may be considerable; but here the value of $D_t v$ is small, and hence the effect of friction, and in the upper regions of the atmosphere where friction must be very much less, the value of i must be small, and $\cos i$ differ but little from unity.

43. In order to compute the expression of $D_t v$ (43), it is necessary to know first the value of a', and this is obtained from (11) with the value of a_0 in (20), a' being the value of a at the surface of the earth, and hence the surface-values of t must be used in (11).

In the case of the mean annual temperatures, we can use the expression of t in (24), and with this we get from (11)—

$$(44).\quad \begin{cases} a' = a_0 \left(0.968 + 0.007 \cos\theta + 0.079 \cos 2\theta + 0.004 \cos 3\theta + 0.007 \cos 4\theta\right) \\ \frac{1}{a'} = \frac{1}{a_0}\left(1.035 - 0.007 \cos\theta - 0.084 \cos 2\theta - 0.004 \cos 3\theta - 0.010 \cos 4\theta\right) \\ \frac{D\, a'}{a'} = \frac{-0.007 \sin\theta - 0.163 \sin 2\theta - 0.012 \sin 3\theta - 0.028 \sin 4\theta}{1 + 0.082 \cos 2\theta} \end{cases}$$

With the value of $\frac{1}{a_0} = g \times 7989^{m}$, obtained from (20), the second of these equations gives the values of $\frac{1}{a'}$ for any given value of the polar distance θ, and the last one gives the values of $\frac{D_\theta a'}{a'}$, from which we get the values of $\frac{D_u a'}{a'}$, or its equal $\frac{D_\theta a'}{r a'}$.

In the case of the January and July temperatures, the values of a' and $\frac{1}{a'}$ must be computed from (11) and (20) with the temperatures or values of t in (11), contained in Table V, for each tenth degree of latitude, interpolated to every fifth degree, and then, by means of the differences, the values of $D_\theta a'$ and of $\frac{D_\theta a'}{a'}$ can be approximately obtained.

In order to express the value of $D_u \log P'$ in terms of the gradients in Table X, we must put—

$$D_u \log P' = \frac{D_u P'}{P'} = \frac{1}{P'} \cdot \frac{G}{111111111}$$

In this way, the values of $D_t v$ have been computed from (43), putting $\cos^2 i = 1$, for each fifth degree of latitude, so far as the data suffice for the purpose, except near the equator, where the formula is not applicable on account of the smallness of $\cos \theta$ in the denominator, and the results are given in the following table. The values of G and $P' = B_0$ in Table X have been used for the purpose. The velocity $D_t v$ is given in kilometers per hour.

TABLE XI.

Lat.	$D_t v$.					
	Mean temperatures.		January.		July.	
°	*km*		*km.*		*km.*	
+ 75	− 4.4	+ 4.8 h.	− 1.9	+ 4.4 h.	− 5.7	+ 5.1 h.
70	− 3.3	6.6 "	− 1.1	7.5 "	4.8	5.8 "
65	+ 0.2	7.7 "	+ 1.6	9.6 "	− 1.2	5.9 "
60	3.9	8.3 "	5.5	10.9 "	+ 2.3	5.6 "
55	5.5	8.5 "	7.0	11.6 "	4.0	5.4 "
50	5.4	8.6 "	6.4	12.1 "	4.4	5.1 "
45	4.9	8.8 "	5.5	12.6 "	4.1	5.0 "
40	+ 2.6	9.0 "	+ 2.8	12.9 "	+ 2.4	4.8 "
35	− 1.2	9.3 "	− 1.0	13.8 "	− 1.4	4.6 "
30	8.6	9.5 "	9.1	14.7 "	8.1	4.3 "
25	14.4	9.4 "	16.0	15.2 "	12.2	3.6 "
20	15.1	9.0 "	20.2	15.6 "	11.7	2.4 "
+ 15	12.5	5.6 "	21.8	10.5 "	3.8	0.6 "
− 15	25.0	8.2 "	18.7	4.9 "	31.0	11.7 "
20	20.9	7.8 "	18.8	5.8 "	23.0	10.0 "
25	−10.3	7.6 "	−10.4	6.6 "	−16.1	8.7 "
30	+ 3.8	7.5 "	+ 2.3	7.3 "	+ 5.2	7.8 "
35	12.4	7.4 "	10.0	7.8 "	14.4	7.1 "
40	18.7	7.4 "	16.0	8.2 "	21.4	6.7 "
45	24.0	7.5 "	21.0	8.6 "	27.0	6.4 "
50	27.5	7.5 "	24.5	8.9 "	30.5	6.1 "
55	27.3	+ 7.5 "	+24.6	+ 9.1 "	+30.0	+ 5.9 "
− 60	+21.9					

44. Since h vanishes at the earth's surface, the first term in the expression of $D_t v$ in this table represents the surface-velocity of the east or west component of motion at the surface. This is a little less than what is usually obtained from the gradients; for the barometric pressures having been reduced to the gravity of the parallel of 45°, the gradients in the middle latitudes are diminished on this account about 0.07^m, which, by (21′), for the temperature of 0°, corresponds on the parallel of 45° to 2.16^{km} per hour. This shows the importance of having all barometric pressures reduced to a fixed measure instead of being expressed in measures which vary with the latitude.

Since h vanishes at the earth's surface, the easterly component of the velocity of the wind there is represented by the first term in the expression of $D_t v$ in Table XI. Between the parallels of 36° and 66° in the northern hemisphere, and south of 29° in the southern hemisphere, as far as barometric observations have been made, the winds, according to the results of this table, have an easterly component, and between the parallels of 36° N. and 29° S. there is a westerly component. North of the parallel of 66° N. there is also a westerly component. By a glance at Plate 3 of the late Prof. Coffin's great work on the "Winds of the Globe," it is seen that this is exactly in accordance with observation, except that the dividing line between the two systems of winds in the southern hemisphere is a little south of the parallel of 29°. But the observations in this zone are not sufficient for determining the position of this line very accurately, and the position obtained from the barometric gradients is, without doubt, the more correct one.

Again, according to the authority of Mr. Laughton,* "In both hemispheres to the north or south of the parallels of 35° or 40°, a strong westerly wind blows with great constancy all around the world.

* Physical Geography in its Relation to the Prevailing Winds and Currents, p. 101.

In the southern hemisphere, more particularly, it blows with a persistence little less than that of the trade-winds, but with a strength which, although fitful, is very much greater. From a fresh, strong breeze, it rises frequently into a violent gale, and, as such, blows for days together, the mean direction being nearly west, from which it seldom varies more than a couple of points on either side. South of the Atlantic, south of the Indian Ocean, south of Australia, in the higher latitudes of the Southern Pacific, and to the southward of Cape Horn, we find it still the same, a westerly gale, whose strength and constancy combined have enabled Australian clippers to make passages which seem to border on the fabulous. In the northern hemisphere, it has not the clear range which it has in the southern; but there, too, it prevails in the most decided manner."

From the results of Table XI, it is not only seen that the velocities in the higher latitudes of both hemispheres are eastward, but that they are very much greater in the southern than in the northern hemisphere, which is exactly in accordance with observation according to the preceding quoted paragraph.

The smallness of the eastward components of velocity in the northern hemisphere compared with those of the southern is due to the greater amount of land and mountain-ranges in the northern hemisphere than in the southern, which increases the resistances to the eastward motions, and consequently the greater eastward motions of the southern hemisphere, by means of the deflecting force arising from the earth's rotation, causes a greater depression there, and a great part of the atmosphere to be thrown into the northern hemisphere. This also accounts for the mean position of the equatorial calm-belt being, in general, a little north of the equator. For the same reason, the tropical calms of the northern hemisphere are farther from the equator than those of the southern hemisphere.

The easterly components for the northern hemisphere are known, from observation, to be very small; but estimates of the actual velocities have been made but for a very few places around the globe. Prof. Coffin obtained* for the average velocity for the whole of the United States, estimated by the Smithsonian scale, 2.0 miles (3.2^{km}) per hour, with a resultant direction nearly from the west, making the eastern component sensibly the same. This result agrees almost precisely with the result given for the mean of the year in Table XI for the average latitude of the United States; but it must be remembered in these comparisons that the theoretical results are those of the average all around the globe, and that various disturbing causes, to be considered hereafter, may cause considerable deviations from this average in different longitudes on the same latitude. The effect of friction at the surface, which has been neglected in the formula (43), is to make the actual velocities less than those given in Table XI by the formula.

The westward velocities in the trade-wind zones, as given in Table XI, are greater in the southern than the northern hemisphere. This is in accordance with observations of the trade-winds of the Atlantic Ocean, on which the southeast trade-winds are observed to be much stronger than the northeast ones. The theoretical results, however, in these zones are probably considerably too large on account of the neglect of the friction term in (43), which in these zones is very much magnified near the equator from the smallness of $\cos \theta$ in the denominator of the formula.

The parallels of 36° in the northern and of 29° in the southern hemisphere, being parallels on which there is no east or west motion on the average around the globe, and where, on account of there being no barometric gradient, there can be no north or south component of velocity, represent the mean position of belts in which calms abound, called tropical calm-belts.

45. From a comparison of the eastward and westward velocities at the earth's surface in both hemispheres, contained in Table XI, it is seen that the winter velocities in each hemisphere are greater than those of summer. We have but few results deduced from observations to confirm this result, but it is completely confirmed so far as they go. From Prof. Coffin's "Winds of the Globe" (pp. 648–653), we extract the following mean directions and true velocities in mean direction for winter and summer, and have computed the corresponding components of velocity contained in the following table.

* Winds of the Globe, p. 641.

TABLE XII.

Region or place.	Mean direction.		True velocity.		East component.		South component.	
	Winter.	Summer.	Winter.	Summer.	Winter.	Summer.	Winter.	Summer.
	°	°	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*	*Miles.*
Red River Settlement	S. 72 W.	S. 85 W.	0.60	1.12	+ 0.57	+ 1.12	− 0.18	− 0.10
Pacific coast	S. 3 W.	N. 80 E.	1.64	1.51	0.09	1.48	− 1.64	+ 0.26
Northern Lake Region	N. 59 W.	S. 55 W.	2.32	1.73	2.05	1.42	+ 1.23	− 0.99
Canada and Nova Scotia	S. 87 W.	S. 64 W.	3.49	2.30	3.49	2.07	− 0.18	− 1.01
New England States	N. 52 W.	S. 66 W.	5.41	2.67	4.26	2.44	+ 3.33	− 1.09
Region of the Missouri	N. 73 W.	S. 37 W.	2.26	1.69	2.16	1.02	+ 0.66	− 1.35
South of the Great Lakes	S. 77 W.	S. 68 W.	2.86	2.13	2.79	1.98	− 0.64	− 0.80
Indiana, Illinois, and Ohio	S. 72 W.	S. 69 W.	2.64	1.67	2.51	1.56	− 0.82	− 0.60
New York to North Carolina west of Appalachian Range	S. 79 W.	S. 77 W.	3.52	2.04	3.45	1.99	− 0.67	− 0.46
Middle States east of the Appalachian Range	N. 72 W.	S. 69 W.	3.42	1.67	3.25	1.56	− 1.05	− 0.60
Kentucky and Tennessee	S. 66 W.	S. 79 W.	2.35	1.00	2.15	0.98	− 0.96	− 0.19
Atlantic coast (latitude 31° to 38°)	N. 70 W.	S. 25 W.	2.68	1.82	2.52	+ 0.77	+ 0.92	− 1.65
Texas (latitude 30°)	N. 3 W.	S. 43 E.	3.59	3.78	0.19	− 2.57	− 3.59	− 2.76
Gulf States	N. 45 W.	S. 22 E.	1.25	1.00	0.88	− 0.38	+ 0.88	− 0.94
Northern Florida	N. 15 W.	S. 5 W.	1.78	1.47	+ 0.46	+ 0.13	+ 1.72	− 1.46
Salt Ponds of Florida (latitude 25°)	N. 30 E.	S. 70 E.	8.11	8.84	− 0.40	− 8.60	+ 0.70	− 2.13
City of Mexico	S. 9 W.	N. 78 E.	3.19	0.88	+ 0.50	− 0.86	− 3.16	+ 0.18
Catharina Sophia, Guiana	N. 58 E.	N. 83 E.	8.73	4.86	− 7.41	− 4.83	+ 4.63	+ 0.59
Horta Fayall, Azores	S. 78 E.	S. 43 W.	1.63	2.14	− 1.59	+ 1.45	− 0.34	− 1.56
Sandwich Manse, Orkney Islands	S. 62 W.	S. 62 W.	6.33	2.86	+ 5.59	+ 2.52	− 3.00	− 1.34
Port Foulke, Arctic Ocean	N. 42 E.	S. 82 W.	17.21	0.47	−11.51	+ 0.46	+12.78	− 0.06
Port Kennedy, Arctic Ocean	N. 44 W.	N. 31 W.	13.08	8.74	+ 9.10	+ 7.60	+ 9.40	− 4.40

By comparing the east components of winter and summer above, it is seen that throughout the United States, except on the Pacific coast and in the extreme southern States, and at the Orkney Islands, the winter component is in every case greater than the summer component. The extreme southern States are so near the parallel of the calm-belt that the velocities in the direction of the resultant, and the direction itself, are so uncertain that the ratios between the components for winter and summer are very various, and the signs of the components even change in some cases.

46. The effect of the second term in the expression of $D_t v$ in Table XI is to increase very much the velocities of the eastward motions in the upper strata of the atmosphere over those at the surface in the higher latitudes; and, in the trade-wind zone, the westward velocities near the surface are at a very moderate elevation changed to eastward velocities. Thus, on the parallel of 45°, and at an elevation of 5 kilometers, we have, for the mean temperature of the year, $D_t v = 4.9^{km} \times 8.8^{h} = 48.9^{km}$ per hour, and at greater elevations this velocity becomes still much greater. On the parallel of 25°, we have $D_t v$ at the surface equal to 14.4^{km} west, and at the elevation of only 3^{km} it becomes 13.8^{km} east, and hence at the elevation of only about 1.5^{km} there is no motion east or west. These results are in accordance with observation, for travelers have experienced a strong westerly wind, at great elevations, on Mauna Loa, on the passes of the Rocky Mountains and the Andes, on the top of Pike's Peak and Mount Washington, on the Peak of Teneriffe, and at every very elevated position in either hemisphere all around the globe, except in the calm-belt near the equator, even when there is an easterly wind in the same latitude in less elevated positions. It is seen from Table XI that in the trade-wind zones, where at the surface the wind is easterly, at a very moderate elevation there is a very strong current from the west; and this is especially the case in the winter. This accounts for the transportation of volcanic ashes through long distances eastward when in the trade-wind belt at the surface there was a strong current from the east. On the 1st of May, 1812, the island of Barbadoes was suddenly obscured by a dense cloud, and its surface quickly covered by a shower of ashes from an eruptive volcano of St. Vincent, more than a hundred miles to the westward. Also, on the 20th of January, 1835, the volcano of Cosequina, lying in the belt of the northeast trade-winds, sent forth great quantities of lava and ashes, and the latter were borne in a direction just contrary to the surface-wind, and lodged on the island of Jamaica, 800 miles to

the northeast. This latter happened at a season when, according to the results of Table XI, the upper currents have a very great easterly tendency, and hence at a time very favorable for the transportation of the ashes to so great a distance. The great eastward velocities of the upper currents are also established by the observations of the clouds, especially of the cirrus clouds, which are supposed to have an altitude generally of 7 or 8 kilometers. The eastward velocity of these clouds has been estimated at times to be as much as 120 miles (193^{km}) per hour, and it rarely happens that they have no eastward tendency. The average, therefore, according to this somewhat uncertain kind of observations, may be put at nearly 100^{km}. This eastward velocity is a little greater than that given by Table XI at the height of the cirrus clouds in the middle latitudes for the mean temperature of the year, but corresponds with that belonging to January.

The eastward motion of the atmosphere in the latitude of the trade-winds is also confirmed by observations made on the directions of the clouds at Colonia Tovar, Venezuela, latitude 10° 26′, as given in the Report of the Smithsonian Institution for 1857 (p. 254). While the motion of the lower clouds was in general from some point toward the east, the observed motion of nearly all the higher clouds was from some point toward the west.

51. From a comparison of the expressions of $D_t v$ in Table XI, for January and July, it is seen that the eastward velocities of the upper strata of the atmosphere are very much greater in winter than in summer. On the parallel of 45°, in the northern hemisphere, we have for an altitude of 5^{km} $D_t v$ equal to 66.1^{km} in January and equal to only 29.1^{km} in July. Results deduced from the discussion of observations made at elevated places for both seasons are needed for comparison with this theoretical result.

On the parallel of 25°, in the northern hemisphere, the height at which there is no east or west motion of the atmosphere by Table XI is 1.1^{km} in January, but 3.4^{km} in July. North of this parallel, these heights, where there is no east or west motion, gradually diminish until at the parallel of 36°, the parallel of the tropical calm-belt, this plane touches the surface. Hence there is an oscillation with the seasons of the height of this plane dividing the west or southwest from the east or southeast winds. This explains the winds of the Peak of Teneriffe, which at the top blow in general from the southwest, while lower down they blow alternately from the northeast and southwest, changing with the seasons. In the summer season, the dividing plane between the two systems of winds blowing in nearly contrary directions, is highest, and is found on the Peak of Teneriffe from observation to be about 1.5 miles high. Prof. Piazzi Smyth, who spent several months on the peak making astronomical observations, on leaving his station at Alta Vista, at the height of 10,700 feet above the level of the sea, on the 25th of August, experienced a southwest breeze, but at an altitude of 6,700 feet it changed to one from the northeast. Returning again on the 30th of August, he experienced a similar change at the same height, the strength of the wind increasing as he ascended, and blowing from the southwest at Alta Vista, as when he left.

47. Since each upper stratum acts upon the one beneath it by means of friction, and that upon the next one, and so on, down to the earth's surface, the force which overcomes the friction between the atmosphere and the earth's surface is the sum of all the deflecting forces depending upon the earth's rotation and upon inertia, and putting F_v' for F_v at the earth's surface, we get from (33)—

$$F_v' = \int_m (2\,n \cos\theta\, D_t u - D_t^2 v)$$

in which m is the mass of the atmosphere. But since the condition of continuity must be satisfied, we must have, at any latitude, just as much air moving south as north, and hence for the whole atmosphere from the surface to the exterior we must have—

$$\int D_t u = 0$$

The first term, therefore, of the preceding equation vanishes, and we have—

$$(45) \qquad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \qquad F_v' = -\int_m D_t^2 v$$

For any unit of surface, this must be integrated with reference to the mass of a column of atmosphere having this unit for a base. Now, we have seen that the eastward velocities of the

atmosphere are much greater above than below, and hence, as the atmosphere of the upper currents approaches the poles, it gradually sinks down, to return, toward the equator, nearer the surface, and $D_t v$, in order to satisfy the conditions, must gradually decrease, and in this case the last member of (45) is positive, that is, the sum of the forces tends to overcome the frictional resistance at the earth's surface to the eastward motion of the atmosphere, and the observed amount of motion depends upon these forces. In the equatorial regions, where the atmosphere ascends, of course the reverse of this is the case, and we have these forces tending to overcome the frictional resistance at the earth's surface to the westward motions there. The force, then, which overcomes the frictional resistances, at the earth's surface, to the eastward motion of the atmosphere, depends upon the sum of the moments of inertia, or of the amounts of velocity lost, of the particles of atmosphere, in passing toward the poles, in the upper regions, where the eastward velocity is greater, and returning toward the equator nearer the earth's surface, where the eastward velocity is less. The force, likewise, which overcomes the resistances to the westward motions at the surface in the zones of the trade-winds, is the moment of inertia lost in the decreasing westward velocities of the atmosphere as it ascends and commences to return in the upper regions toward the poles.

48. The eastward velocity $D_u v$ in Table XI is that which satisfies the conditions of the problem in the case of no friction, in which case $D_t u$, the interchanging velocity between the equatorial and polar regions, vanishes, and consequently the deflecting force overcoming friction in the case of friction. Where there is friction there must be a force to overcome it, and hence $D_t u$ must have a value, that is, there must be a gradual interchange of atmosphere between the equatorial and polar regions, and this motion must be just sufficient to give rise to a force sufficient to overcome the friction and the inertia of the eastward motions. If the velocity of the motion of the upper strata of the atmosphere toward the poles were a little too great, it would give rise to an increased eastward velocity, which, by means of the deflecting force depending upon the earth's rotation (§ 13), would at once diminish the velocity, and reduce it to that which satisfies the conditions of the problem.

The difference between the atmospheric pressure at the equator and the poles, at the earth's surface, depends almost entirely upon the eastward motion, or value of $D_t v$, at the earth's surface, as may be seen from the first of (15), since h in the last term vanishes at the surface, and consequently this difference is entirely independent of the difference of temperature, which affects only the last term of this equation. Hence, in the northern hemisphere, where there is a difference of 30° or more in the higher latitudes, between winter and summer, the difference of barometric pressure amounts to only about 2^{mm}. The reason of this is that the increased eastward velocities in winter, as shown in Table XI, give rise to a force depending upon the earth's rotation by the principle of § 13, which tends to prevent the flow of the atmosphere in the upper regions from the equatorial to the polar regions, as the volume there is contracted by diminution of temperature, and the height of the atmosphere is decreased toward the poles, nearly in the same proportion that its density is increased by the diminution of temperature, so that there is scarcely any change in the mass of the atmosphere, and consequently in the barometric pressure, between winter and summer.

If the earth had no rotation on its axis, this deflecting force depending upon its rotation would not exist, and then, if this great difference of temperature between the equator and the poles could be maintained, there would be a very great difference of pressure and a very rapid interchanging motion between the equatorial and polar regions.

END OF THE FIRST PART.

LIST OF SKETCHES.

PROGRESS SKETCHES.

No. 1. General progress.

2. Section I, Northern part.

3. Section I, Primary triangulation between the Hudson and Saint Croix Rivers and Lake Champlain.

4. Section II, Triangulation and geographical positions in Section II, from New York City to Point Judith.

5. Section II, Triangulation and geographical positions in Section II, from New York City to Cape Henlopen.

6. Section III, Chesapeake Bay and tributaries.

7. Section IV, Coast of North Carolina, including Albemarle and Pamlico Sounds.

8. Section III, Primary triangulation between the Maryland and Georgia base-lines (northern part).

9. Sections IV and V, Primary triangulation between the Maryland and Georgia base-lines (southern part).

10. Section V, Coast of South Carolina and Georgia.

11*a*. Section VI, East Coast of Florida (Amelia Island to Halifax River).

11*b*. Section VI, East Coast of Florida (Halifax River to Cape Canaveral).

12. Section VI, West Coast of Florida (Tampa Bay and vicinity).

13. Section VII, West Coast of Florida (Saint Joseph's Bay to Mobile Bay).

14. Section VIII, Coast of Alabama, Mississippi, and Louisiana.

15. ————, Geodetic connection of the Atlantic and Pacific coast triangulations (Section from Saint Louis westward).

16. Section IX, Coast of Texas.

17. Section X, Coast of California (lower sheet), from San Diego to Point Sal.

18. Section X, Coast of California (middle sheet), from Point Sal to Tomales Bay.

19. Section X, Coast of California (upper sheet), from Tomales Bay to the Oregon line, and Section XI (lower sheet), from the California line to Tillamook Bay.

20. Section XI (upper sheet), from Tillamook Bay to the Boundary.

21. Section XII, Explorations in Alaska.

ILLUSTRATIONS.

22. Mount Saint Elias and Coast Range to Cape Spencer. } (See Appendix No. 10, page 160.)

23. Mount Saint Elias. Mount Fairweather. }

24. Curves of Velocity and Density and relative position of Sea and River Waters. South Pass Bar. (See Appendix No. 11, page 190.)

25. Whangaroa Harbor. Chatham Island. (See Appendix No. 13, page 232.)

26. Recording Relay. (See Appendix No. 15, page 250.)

27. Theodolite Magnetometer. (See Appendix No. 16, page 255.)

28. Alt-Azimuth and Magnetometer. (See Appendix No. 16, page 259.)

29. Dip Circle. (See Appendix No. 16, page 264.)

29 bis. Dip Circle (Kew observatory). (See Appendix No. 16, page 264.)

30.* Illustrations of Harbor and River Improvements. (Appendix 18.)

31 to 37. Charts I to VII, to illustrate Appendix 20. Meteorological Researches.

STATISTICS

Of Field and Office work to 1872 inclusive.

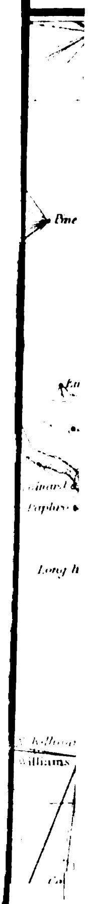
LAND WORK		HYDROGRAPHY	
Triangulation		Soundings	
Area in square miles	61,909	Number of casts	11,313,145
Extent of general coast, in miles	5,386	Miles run while sounding	256,505
Extent of shore line, in miles including Bays, Sounds, Islands and Rivers	25,500	Area sounded out, in square miles	64,776
Geographical positions determined	13,821	Number of specimens of bottom preserved	9,698
Base Lines		Currents	
Primary, number of	13	Number of stations occupied	1,130
Secondary, number of	92	Tides	
Length of, in miles	283¼	Number of stations occupied permanently	8
Astronomical Operations		Number of stations occupied temporarily	1,387
Number of stations occupied for Azimuth	118	Gulf Stream	
Number of do. Latitude	202	Soundings for temperature, number of casts	4,072
Number of do. Longitude	255	Miles run while sounding	11,793
Topography		Reconnaissance on the Western Coast	
Area in square miles	22,405	Extent of coast in miles	2,500
Length of general coast, in miles	5,386		
Length of shore line, in miles	62,140		
Magnetic Elements			
Number of stations occupied	337		

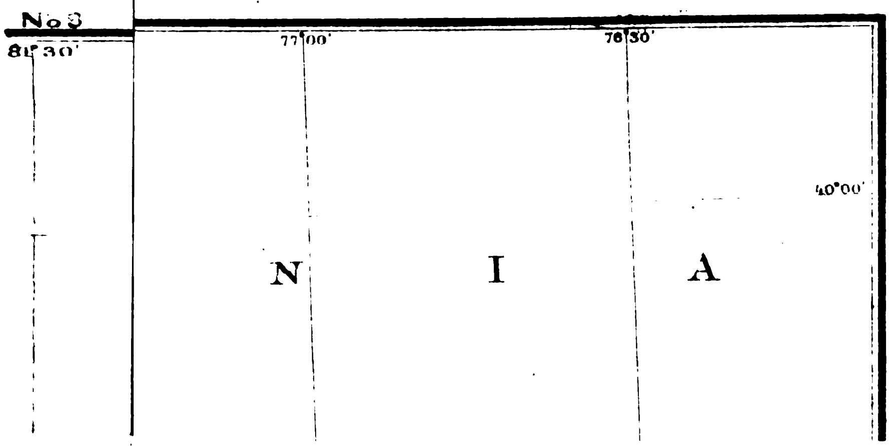
OFFICE WORK

Plane Table Sheets		Hydrographic Sheets	
Number of	1,308	Number of	1,188
Records		Records	
of Triangulation, number of vols.	1,566	of Soundings and angles, number of vols.	6,241
of Astronomical observations "	909	of Tides and currents	2,335
of Magnetic "	298	of Sheets from self registering tide gauges	2,051

PUBLICATION

Finished Charts of Coast, of Harbors and Rivers	172
Preliminary Charts and Hydrographic Sketches	551




77°00'
76°30'
40°00'
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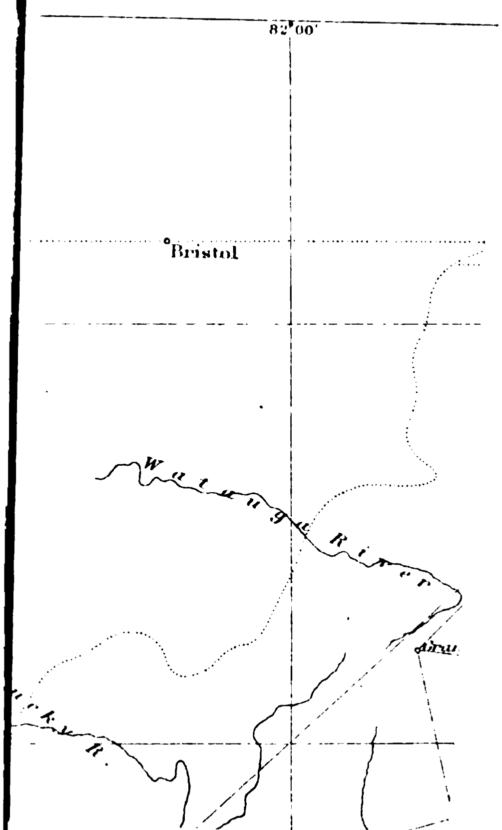
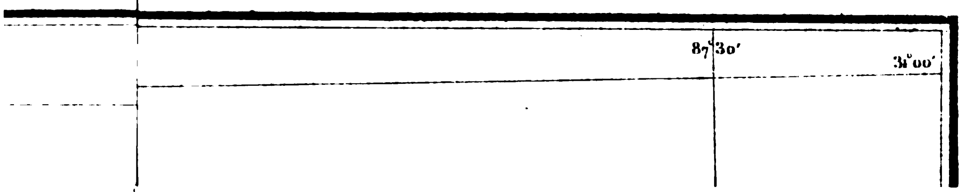
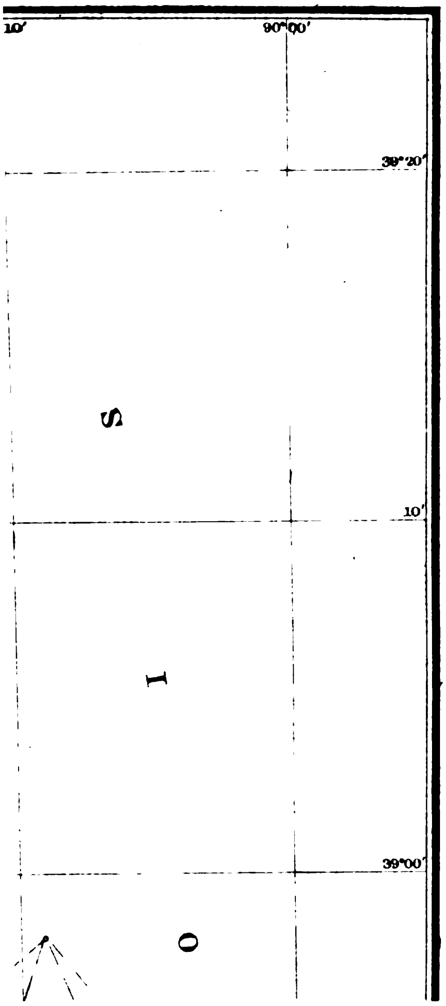
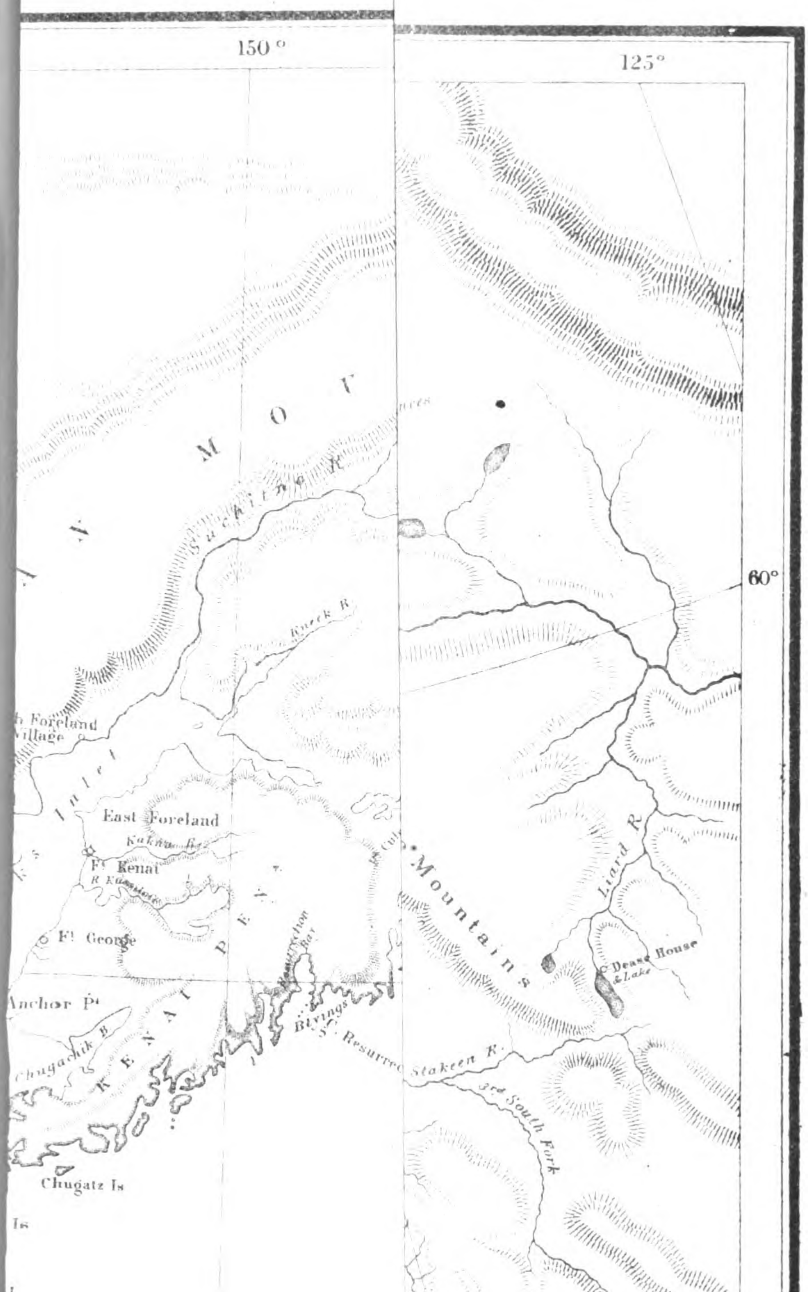
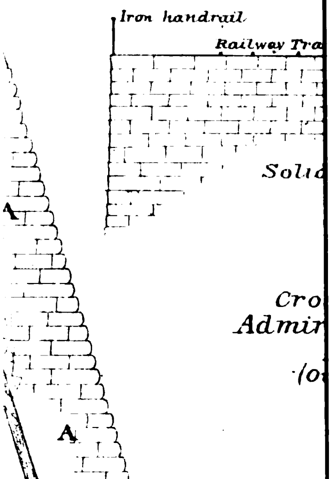

82°00'
Bristol
Watauga River
R.


83°00'
82°50'

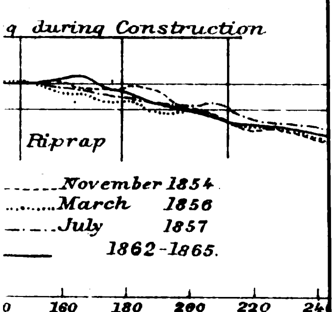

87°30′
31°00′


10'
90°00'
39°20'
S
10'
I
39°00'
O


150°
125°
60°
Knick R.
Foreland
Village
Inlet
East Foreland
Ft Kenai
Ft George
Anchor Pt
KENAI
Chugatz Is
Mountains
Liard R.
Dease House
& Lake
Stakeen R.
3rd South Fork



(7)
l Breakwater
ion 100, near the Bend,
eaviest seas break.



(8)
nd Breakwater
ion 200, near the Fort.

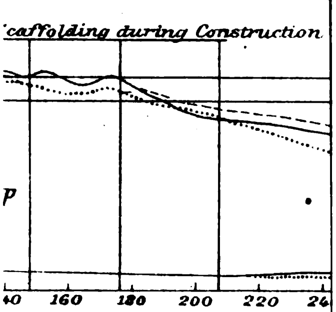


CHART I.

Showing by Isobaric Lines the Mean Annual Pressure of the Atmosphere in Millimeters, reduced to the gravity of the Parallel of 45°, and by arrows the prevailing Directions of the Wind, for the Northern Hemisphere.

** * denote Calms.*

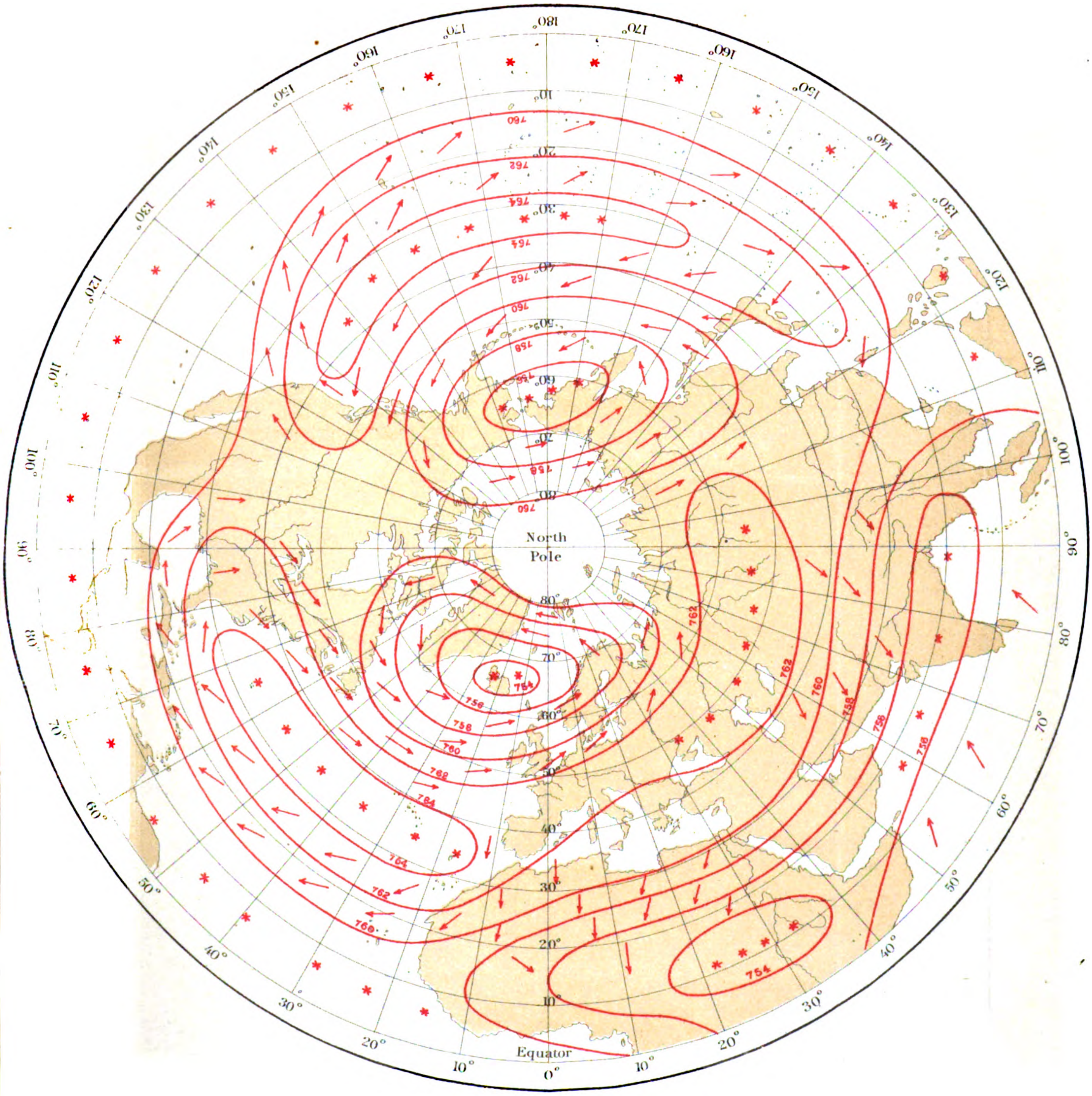


CHART II.

*Showing by Isobaric Lines the Mean Annual Pressure of the Atmosphere in Millimeters, reduced to the gravity of the Parallel of 45°, and by arrows the prevailing Directions of the Wind, for the Southern Hemisphere. * * denote Calms.*

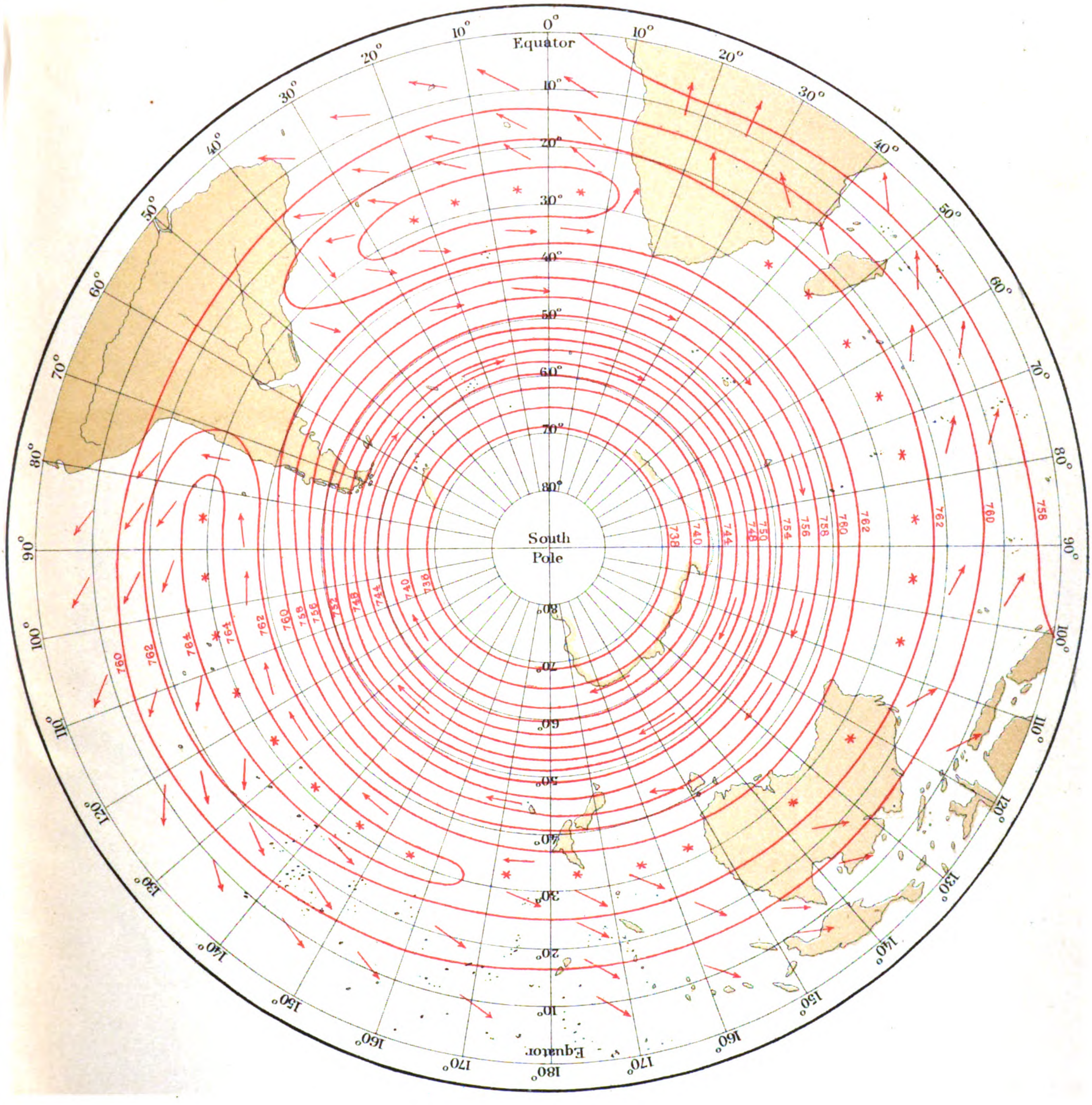


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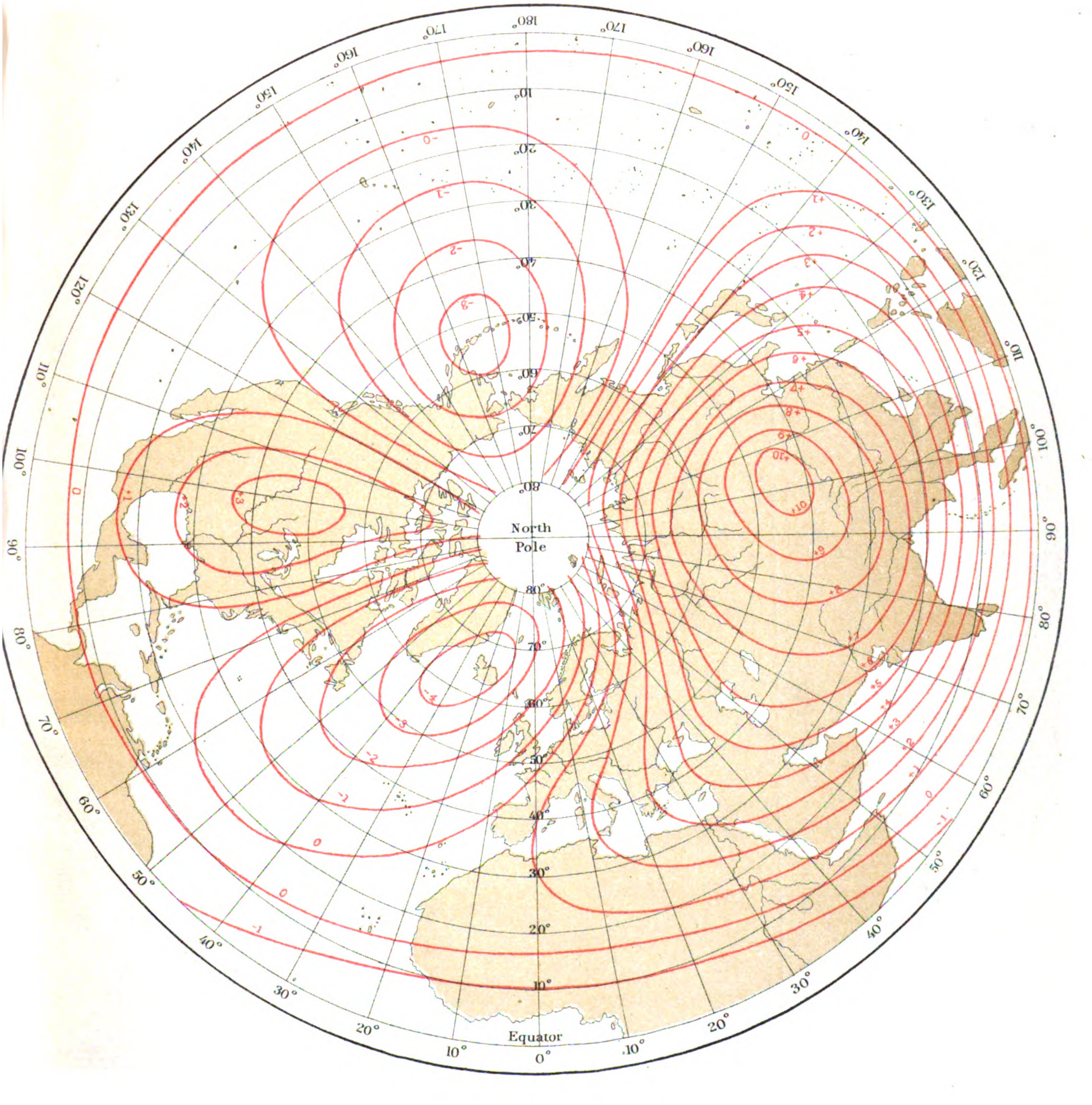
CHART III.

Showing the Coefficient of Annual Inequality of the Atmospheric Pressure in Millimeters, for the Northern Hemisphere.



N° 34

CHART IV.

Showing the Coefficient of Annual Inequality of the Atmospheric Pressure in Millimeters, for the Southern Hemisphere

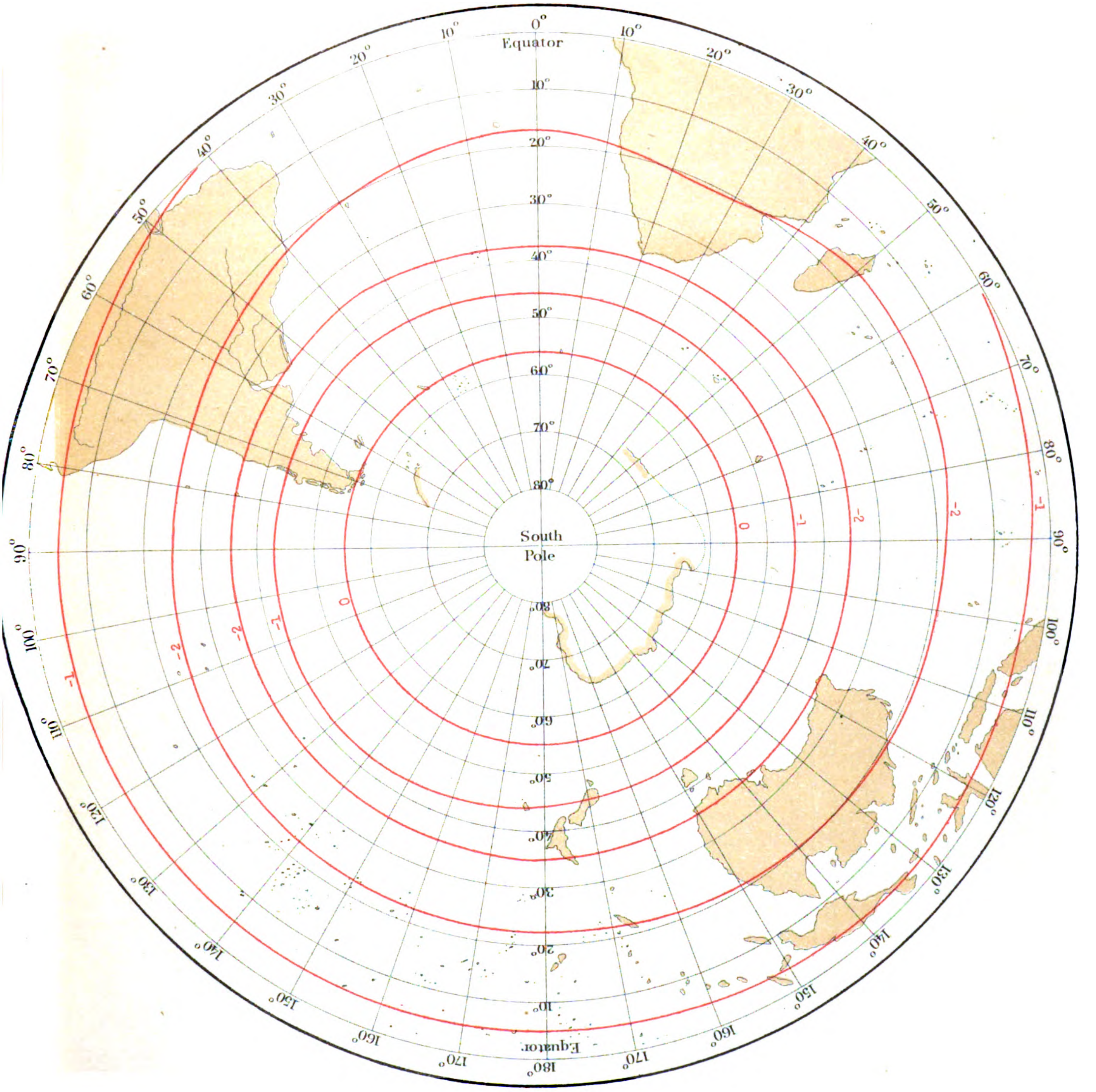


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CHART V

Showing by Isobaric Lines the Mean Pressure of the Atmosphere for January in Millimeters, reduced to the gravity of the Parallel of 45°, and by arrows the prevailing Directions of the Wind, for the Northern Hemisphere.

** * denote Calms.*

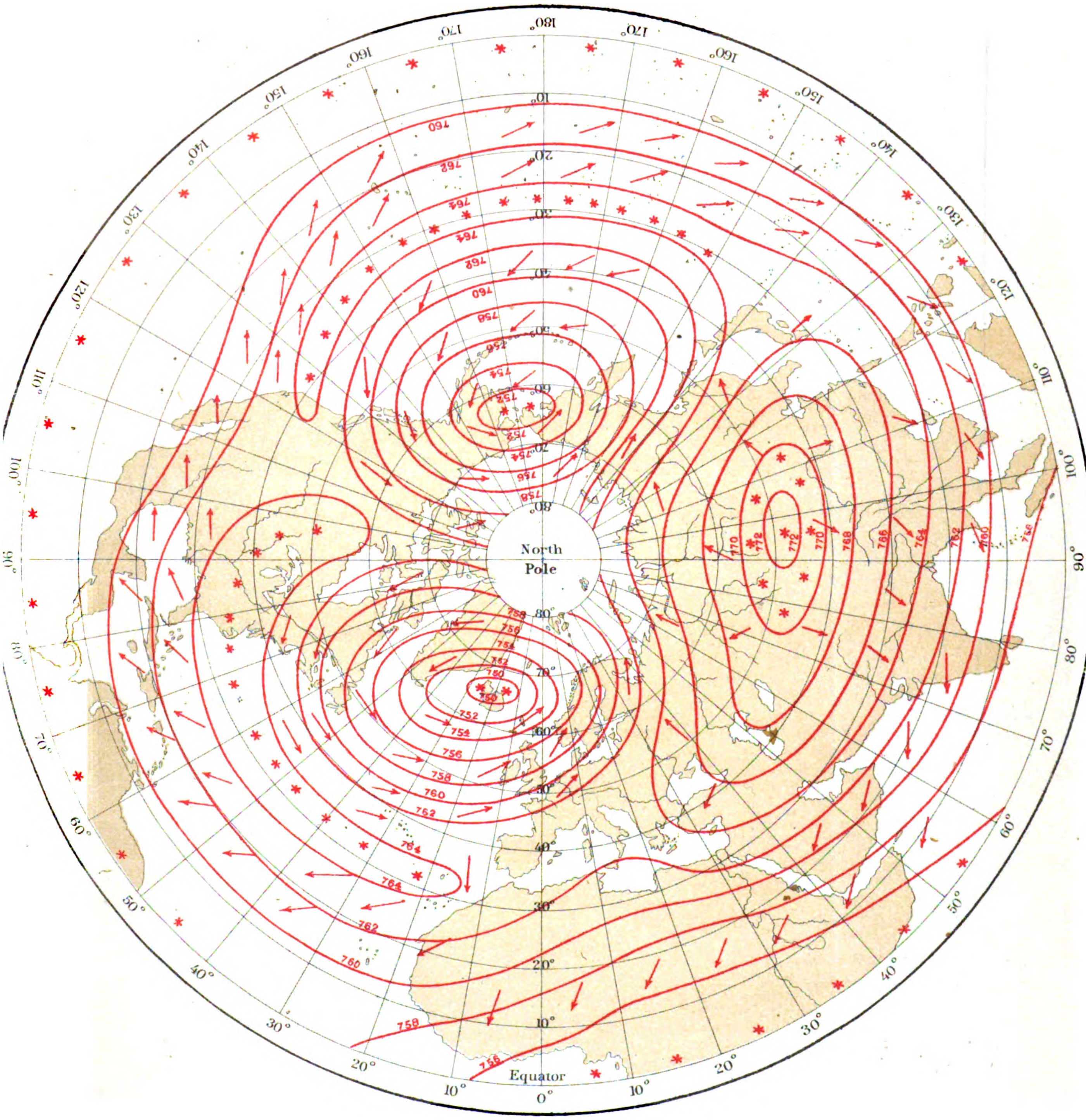

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CHART VI.

Showing by Isobaric Lines the Mean Pressure of the Atmosphere for July in Millimeters, reduced to the gravity of the Parallel of 45°, and by arrows the prevailing Directions of the Wind, for the Northern Hemisphere.

** * denote Calms.*

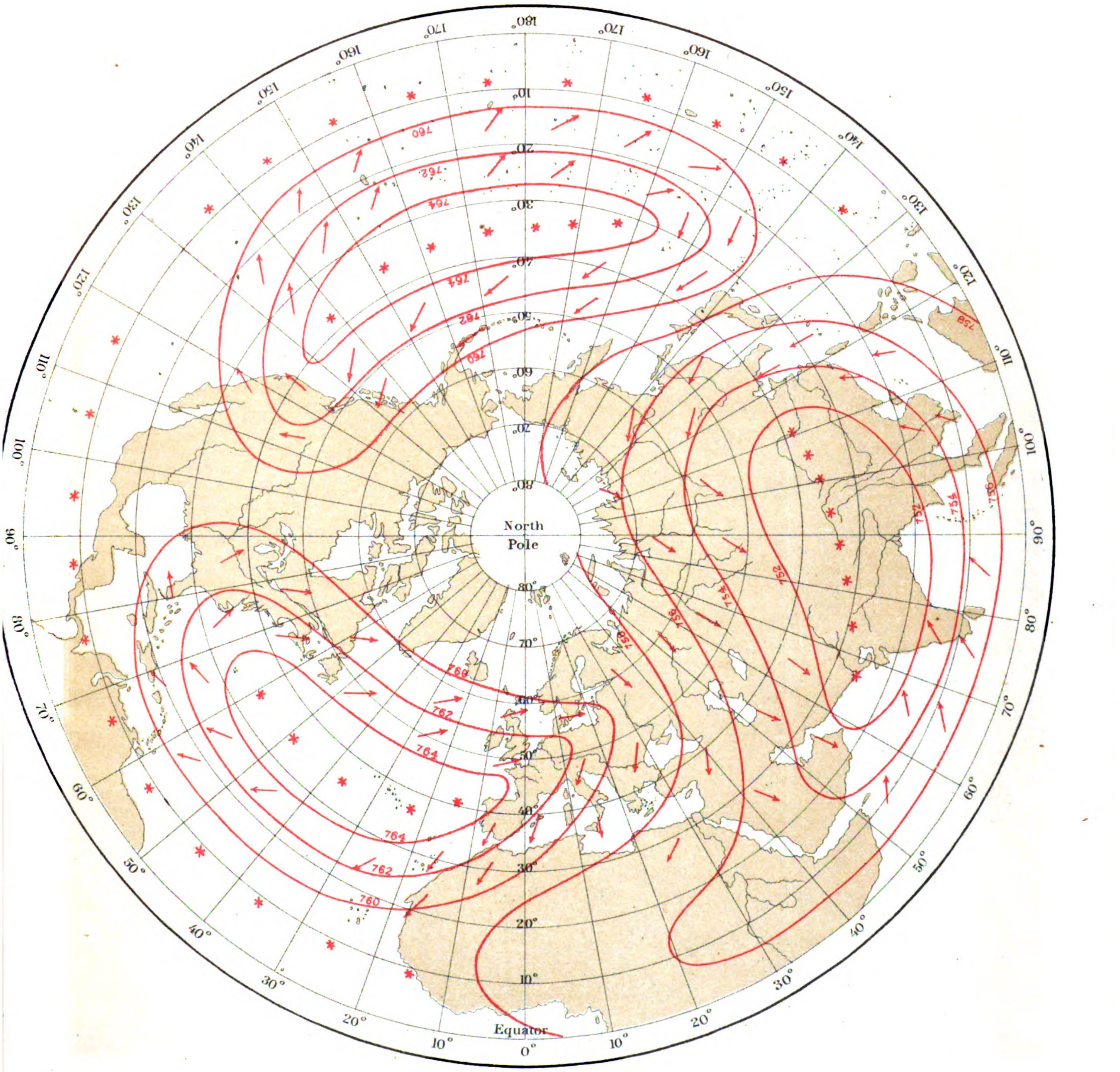

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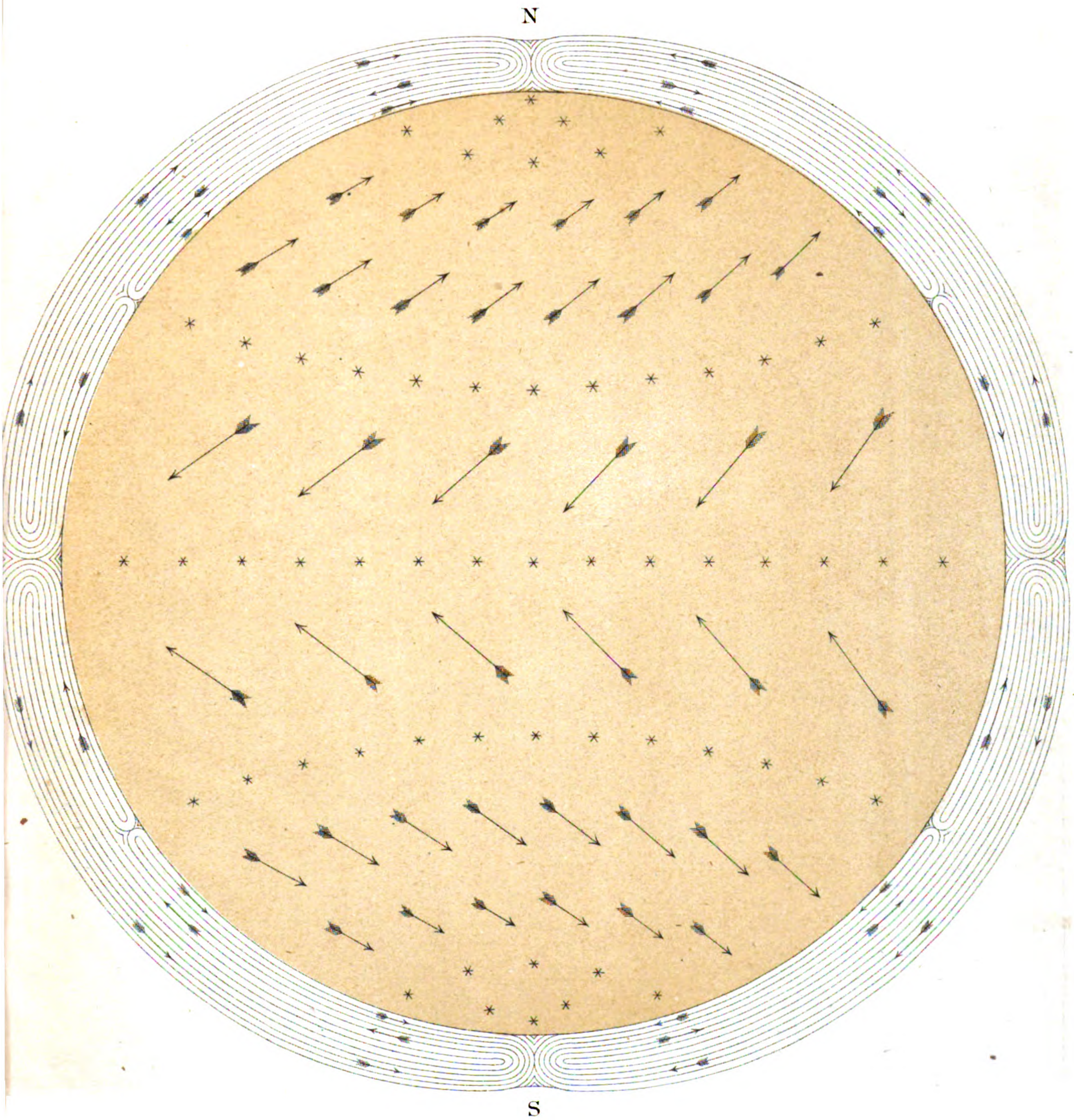
CHART VII.

Showing the Mean Vertical and Horizontal Motions of the Atmosphere in the case of a Homogenous Surface of the Earth in the two Polar Hemispheres.

** * denote Calms.*



37 37